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A COMPUTER-AIDED AERIAL PHOTOGRAPHIC ANALYSIS OF FIRE ISLAND IN--ETC(U)
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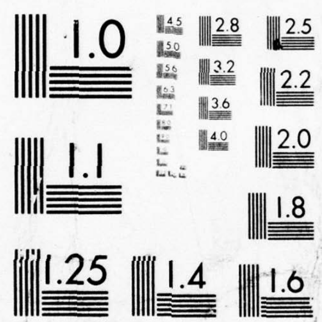

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A COMPUTER-AIDED AERIAL PHOTOGRAPHIC ANALYSIS OF FIRE ISLAND INLET GEOMORPHOLOGY

by

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September 1977

Final Report

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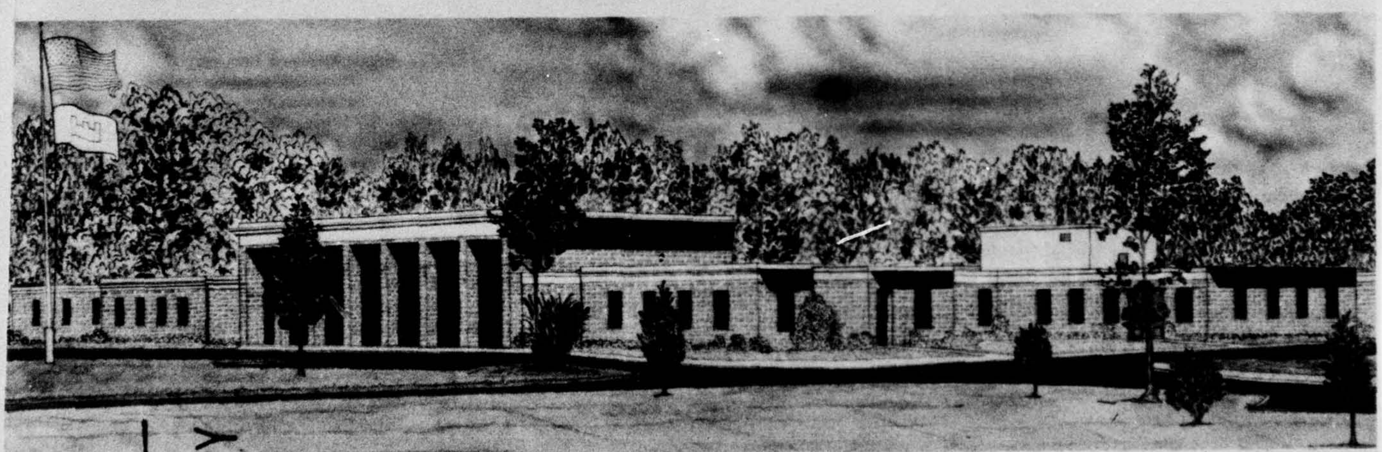

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Geomorphology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In order to provide information on channel location and configuration and assist in planning of dredging operation, the geometry of Fire Island Inlet, New York, is analyzed. Using the 18 sets of aerial photographs taken between April 1962 and April 1972, the locations of shoals, beaches, and channels were determined, digitized for computer analysis, and displayed on drum plots. One of two channel locations proposed by the New York District is considered more appropriate in terms of matching the average channel location.

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PREFACE

A request for the U. S. Army Engineer Waterways Experiment Station (WES) to conduct an investigation of the geometry of Fire Island Inlet, New York, was made by the U. S. Army Engineer District, New York (NAN). Funds were authorized by NAN on 9 December 1974. The study was conducted during the period from January 1974 to August 1977 in the Coastal Branch, Wave Dynamics Division, Hydraulics Laboratory, under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, Dr. R. W. Whalin, Chief of the Wave Dynamics Division, and Dr. C. L. Vincent, Chief of the Coastal Branch.

1LT John H. Barwis, CE, and CAPT Frederick C. Perry, CE, of the Hydraulics Laboratory, and Dr. Victor E. LaGarde of the Mobility and Environmental Systems Laboratory conducted the study. Mr. W. D. Corson and Dr. C. L. Vincent assisted in the preparation of the report.

COL G. H. Hilt, CE, and COL John L. Cannon, CE, were the Directors of WES during the conduct of the study and the preparation and publication of this report. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) AND METRIC (SI) TO U. S. CUSTOMARY UNITS OF MEASUREMENT

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
	U. S. Customary to Metric (SI)	
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
cubic yards	0.7645549	cubic metres
	Metric (SI) to U. S. Customary	
centimetres	0.3937007	inches
metres	3.280839	feet
kilometres	0.613711	miles (U. S. statute)
square kilometres	0.3861021	square miles (U. S. statute)
cubic metres	1.30795	cubic yards

A COMPUTER-AIDED AERIAL PHOTOGRAPHIC ANALYSIS OF FIRE ISLAND INLET GEOMORPHOLOGY

PART I: INTRODUCTION

Background

1. Navigation through Fire Island Inlet is hindered by frequent changes in the position and configuration of the main entrance channel, its associated ebb tidal delta, and the digitate spit at Democrat Point. The secondary entrance channel located farther west, near Cedar Beach, is unsuitable for navigation because of its oblique orientation with respect to the incident angle of the predominant waves.

2. The U. S. Army Engineer District, New York, has designed an entrance channel and associated littoral trap to be maintained by dredging. Quantitative review of historical morphologic changes would be valuable in two respects. First, it would provide information on the location and configuration of the most commonly occurring natural channel. Second, it would provide assistance in long-range planning of dredging operations by locating the areas likely to experience the highest shoaling rates based on historical trends.

3. Previously flown aerial photography provides the only accurate, efficient data base for defining past morphologic changes, since hydrographic surveys have been too infrequent to allow analyses of the short-term instability of inlet features. Photographs are relatively inexpensive and offer a quick, convenient method for analyzing inlet changes.

Objectives and Scope

4. Objectives of this study were to prepare photographic data describing positions of component features of the Fire Island Inlet system, and to quantify temporal shifts in the positions and areas of those features. The project was limited to a consideration of inlet conditions occurring after the March 1962 storm, within an area of

approximately 22 km^2* defined on the east by the Fire Island Bridge and on the west by Cedar Beach (Figure 1a). These limits were decided upon through discussions with New York District personnel.

5. Conditions of component features were studied with respect to both annual and seasonal changes. The features mapped were:

a. Democrat Point Spit boundary.

b. Ebb tidal delta perimeter.

c. Flood tidal delta perimeter.

d. Beach foreshore on all beaches.

e. Beach backshore on all beaches.

f. Tidal channel center lines.

g. Developed areas.**

h. Dunes.**

i. Offshore bars.**

Approach

6. This study involved four major activities: interpretation of data from aerial photographs, digitization, computer analysis, and display of data. Photographs were chosen to reflect both fall and spring conditions, and for the most part were low altitude, panchromatic imagery available commercially (Table 1).

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units and metric (SI) to U. S. customary is presented on page 3.

** These features were mapped for future reference; no analyses were performed for this report.

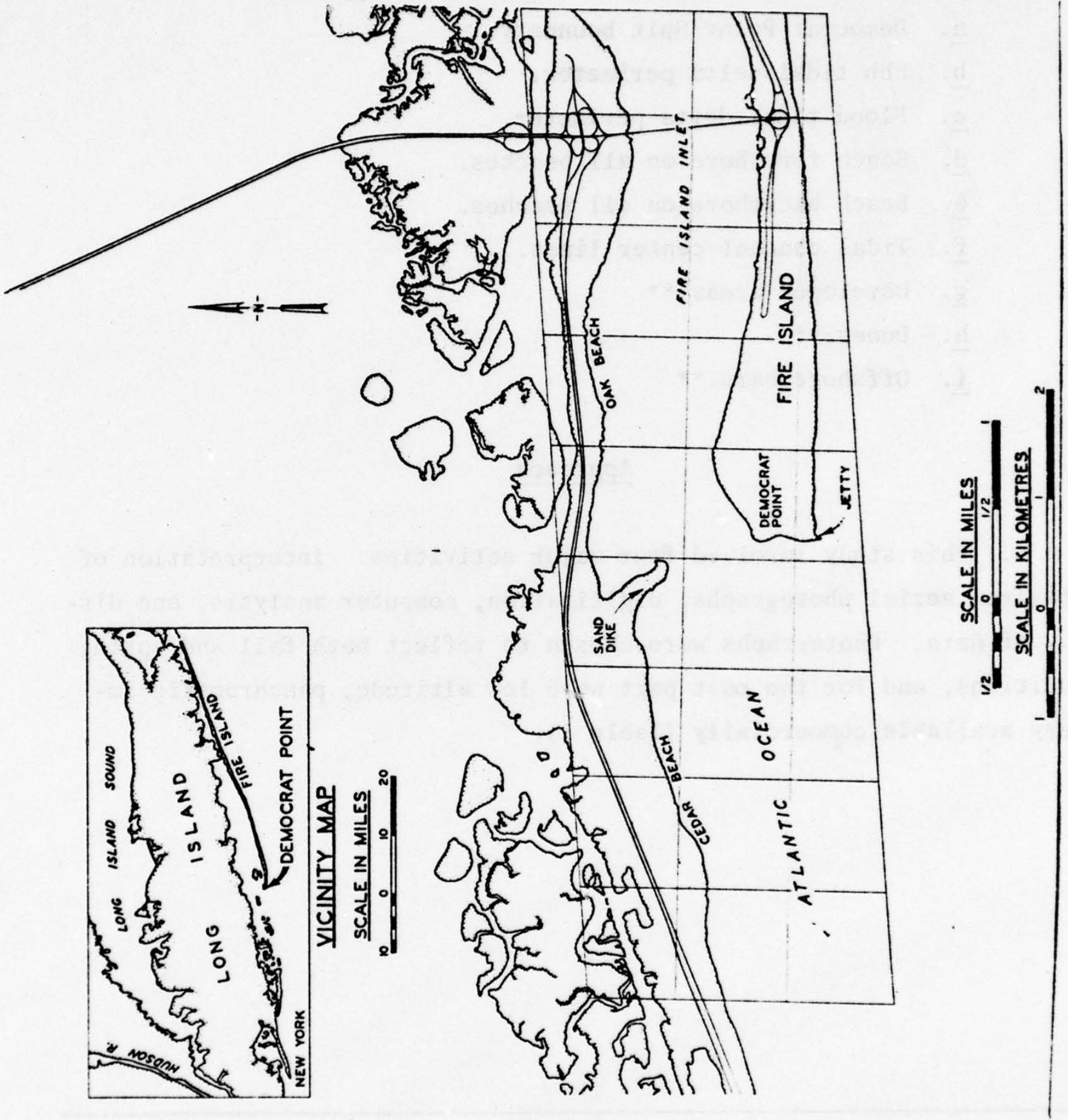

Figure 1a. Location map

PART II: PROCEDURE

7. The 18 sets of photographs listed in Table 1 were selected for study based on the following criteria:

a. Proximity of date to April-May or September-October time periods.

b. Scale amenable to enlargement to a minimum of 1:20,000.

c. Coverage of entire site boundary.

8. Semicontrolled photomosaics at differing scales were constructed for each set of photographs, using transparent overlays made from the "Bay Shore West" U.S.G.S. 7-1/2-minute quadrangle sheet. Six control points common to all mosaics were located for use in scaling. Reduced mosaics are presented in Appendix A.

Photo Interpretation

9. Transparent plastic sheets were laid over each mosaic and the following information was delineated:

a. Location of jetties, groins, seawalls, and piers, along with the State Park parking lots (for ease in visual reference).

b. Location of the beach shoreface, defined as the "step" or break in slope at the seaward edge of the foreshore zone, and identified as a high photographic density contrast line, in or near the breaker zone. When breakers obscured this line, the delineation was drawn by approximation by interpreting wave heights and refraction patterns.

c. Location of the berm crest, defined as the upward limit of wave uprush for the previous high tide, and identified by an obvious grey tone contrast. This line separates the foreshore and backshore zones.

d. Location of the dune scarp, defined as the steep slope at the seaward edge of dune areas. This line is identical with the boundaries of overwash fans, which then appear in the plots as major reentrant angles in the scarp. Where the dunes have been obliterated by recreational development, the scarp was delineated by continuing the scarp trends of immediately adjacent areas.

e. Perimeter of flood tidal delta. This delineation was

drawn along the break in slope at the edge of the main middle ground shoal (Figure 1b). In areas where perimeter slopes were gradual and no breaks in slope were evident, the perimeter was drawn by approximating a line of highest photo density contrast.

f. Perimeter of ebb tidal deltas. This delineation was drawn along the breaks in slope at the edges of the main outer bar and the shoal off Cedar Beach (Figure 1b). In areas of gradual slope where no break in slope was evident, the perimeter was drawn by approximating a maximum grey tone contrast line.

g. Trace of main channel center line, defined as the locus of points midway between bank and shoal areas of equal grey tone density.

h. Perimeter of longshore bars, defined by breaks in slope where possible, or by areas of offshore breaking waves.

i. Limits of developed areas behind the dune scarp.

10. Six control points of known ground separation were recorded for use in calculating the exact scale of each photomosaic. Only the two most widely separated points were subsequently used for scaling.

Digitization

11. The overlays resulting from photo interpretation were digitized and placed on computer files using the following procedure. The overlay was taped onto the active area of a digitizer table. The x, y coordinates of any position within 0.005 inch could then be digitized by positioning a lightweight crosshair cursor over the position. The x, y coordinates of that position were automatically placed on magnetic tape by depressing a button on the cursor. By keeping the button depressed, an essentially continuous trace can be obtained. The x, y coordinates of all delineated regions on the interpreted overlays, as well as a code number identifying the region, were digitized by following the delineations with the cursor. The data on magnetic tape were then placed on computer files for subsequent analysis. Figure 1b identifies each area with its respective code number.

12. Locations of photomosaic control points were digitized from the U.S.G.S. "Bay Shore West" 7-1/2-minute quadrangle sheet (1:24,000)

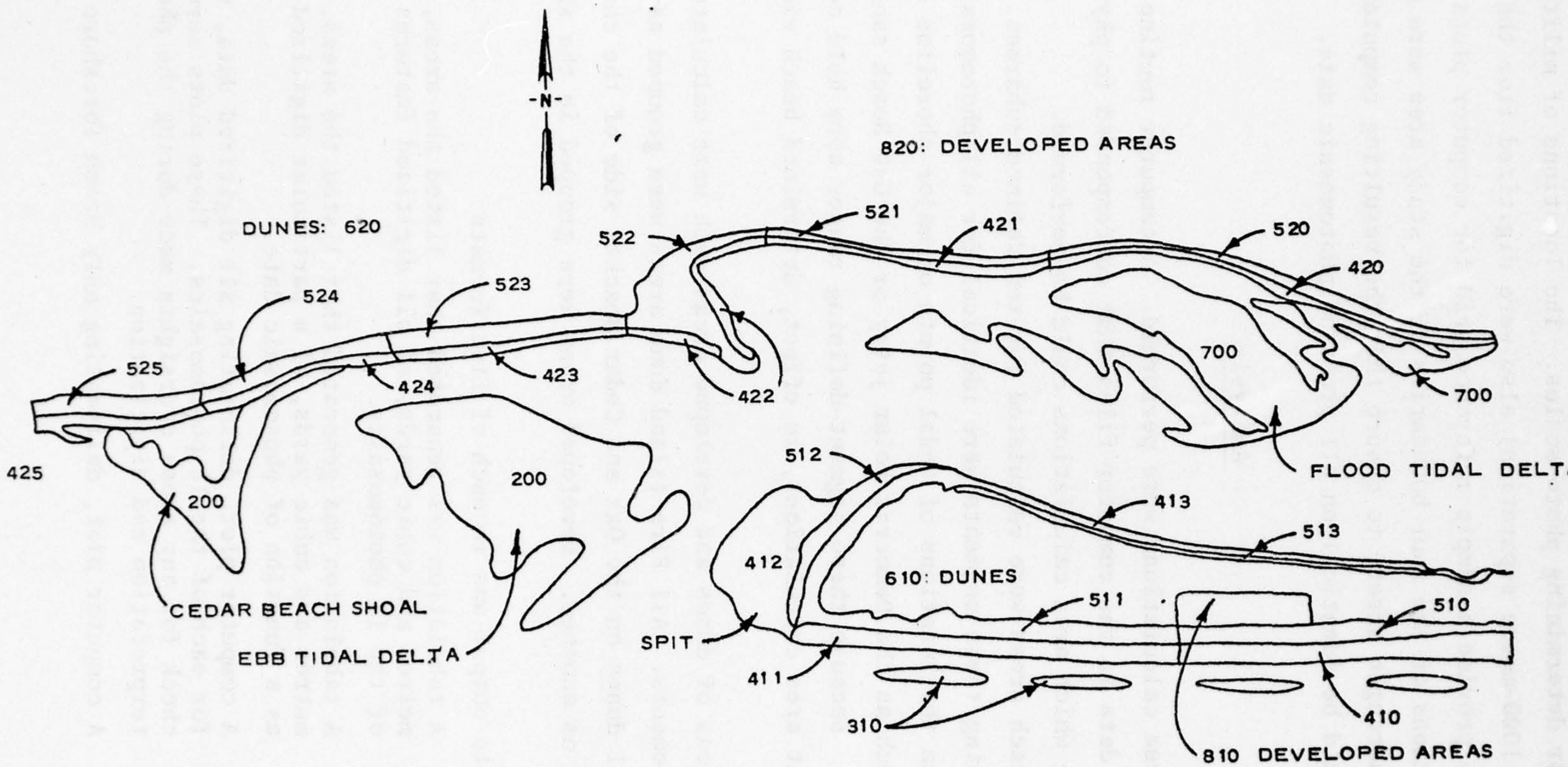

Figure 1b. Fire Island geomorphic units

as a base for determining photo scales. The locations of military grid lines (UTM, 1000-metre separation) also were digitized from the quadrangle sheet to provide a sample reference grid for computer plots of the data. Locations of the four boundaries of the study area were digitized from the quadrangle sheet, to ensure that the resulting computer-imposed boundary would be identical on all plots of photomosaic data.

Analysis

13. Area calculations were performed. A computer routine located all sets of data in the computer files that corresponded to physical features for which area calculations could be performed.

14. Beach areas were calculated for ten defined subareas. The ranges defining these segments were identical for all photomosaics and were based on the locations of nodal points or major shoreline discontinuities such as the Democrat Point jetty or the Oak Beach sand dike (Figure 1a). Because these segment-defining ranges were held constant, the resultant area calculations, in effect, determined beach width changes.

15. Areas of dunes and developed areas each were calculated for two major elements. All Fire Island dune areas were grouped as one area, and all dunes on the Oak and Cedar Beaches side of the channel were grouped as another. Developed areas were grouped in the same manner.

16. Data output was in each of five formats:

- a. A tabulation was generated that listed the areas, in cubic metres and cubic yards, of all digitized features for each of the 18 photomosaics.
- b. A tabulation was generated that listed the areas, in cubic metres and cubic yards, of a particular digitized feature as a function of photomosaic date.
- c. A computer plot, delineating all digitized data, was drawn for each of the 18 photomosaics. These plots served as a check for any gross oversights made during the photo interpretation and digitization.
- d. A computer plot, delineating only beach foreshore areas

and tidal deltas, was drawn for each of the 18 photomosaics. These plots provided an uncluttered base for a sequential review of changes in shoal and channel configurations.

e. The positions of tidal deltas on each of the 18 photomosaics were overplotted on a single sheet at the same scale. This plot provided a visual indication of the areas most often occupied by particular shoals and channels.

PART III: EVALUATION OF RESULTS

Plot Routines

17. As a check against oversights or mistakes in digitizing, separate drum plots were drawn for all photomosaics. Each plot was drawn at 1:10,000 and included all information digitized from the photomosaics. These plots are presented in reduced size in Figure 2. When viewed in chronological order, the plots provide a historical sketch of areal changes in all geomorphic components studied. As an example, the large reentrant angles along the dune scarp on the southern shore of Fire Island are washover fans caused by the March 1962 storm. Successive plots show reestablishment of the dunes in this area. Also evident is the continual elimination of stabilized dunes as a result of construction projects. Other geomorphic components that can be monitored are the width of the backshore zone, positions of longshore bars, and the main channel center-line trace.

18. Because comparisons of specific geomorphic features (e.g. tidal deltas) were required, CRT drum plots were drawn that depict only tidal deltas, the spit, and beach foreshore areas (Figure 3). Chronological review provides a rough indication of historical changes in shoal-channel configurations. Data output in this format also provided input for analyses of mean channel location and the frequencies of occurrence of shoal locations. As will be discussed later, note that:

- a. Position of the flood tidal delta is relatively constant.
- b. The sizes and positions of Democrat Point spit, the ebb tidal delta, and Cedar Beach shoal are highly variable.
- c. The main channel* appears to have oscillated around each of two main positions: one proximal to the spit, and one proximal to the Cedar Beach shoal.

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* Here it should be noted that the term channel is to imply nonshoal regions. It is impossible to assign a depth to the channel or to indicate that the region is of navigable depth. The same is true of the shoals. Although an area may be termed a shoal it may possibly be navigable. It is the shoal-channel contrast that is important. In this usage, channel areas are deeper than shoal areas because the bottom is too deep in the channels to be seen in the photograph.

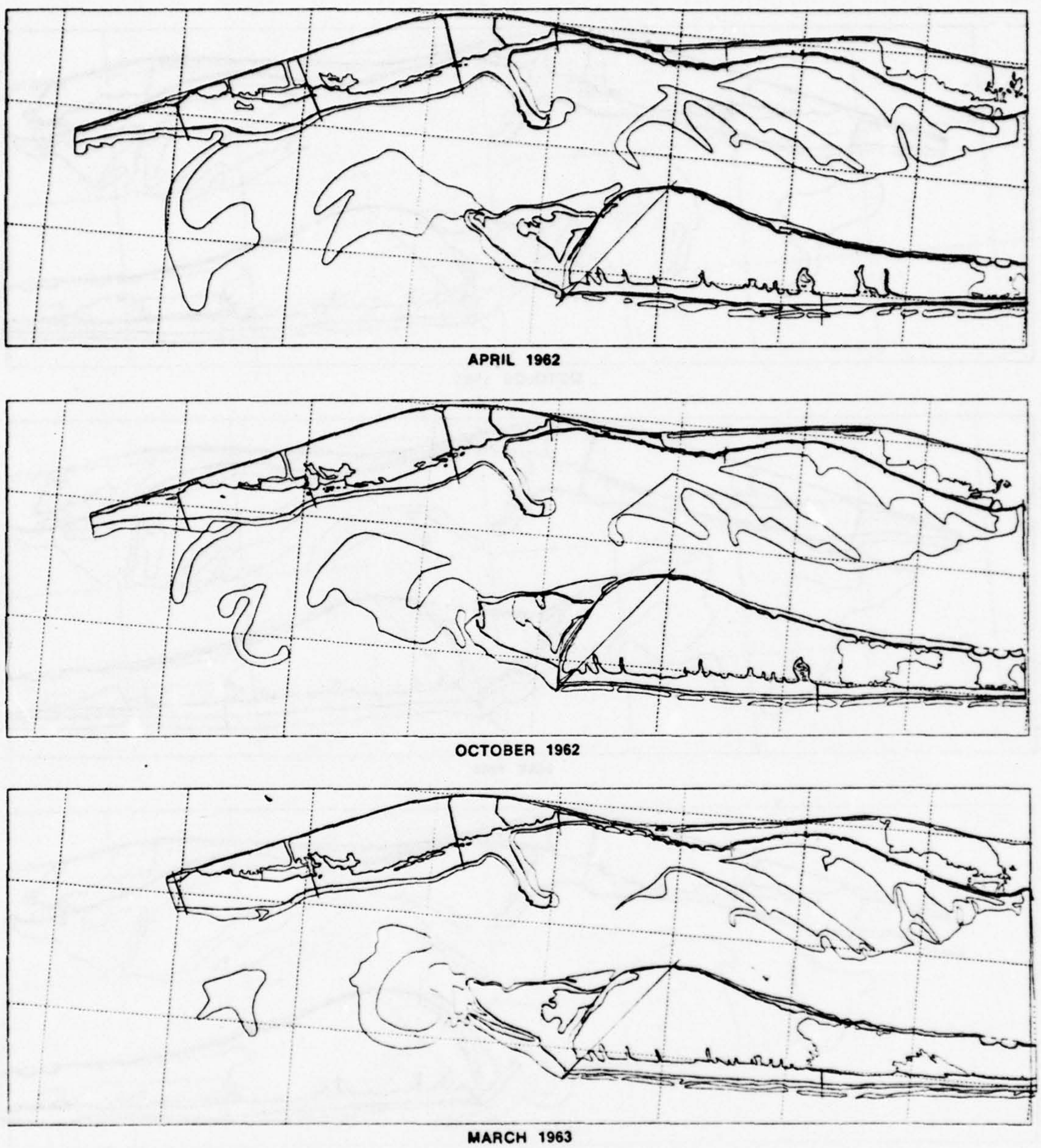
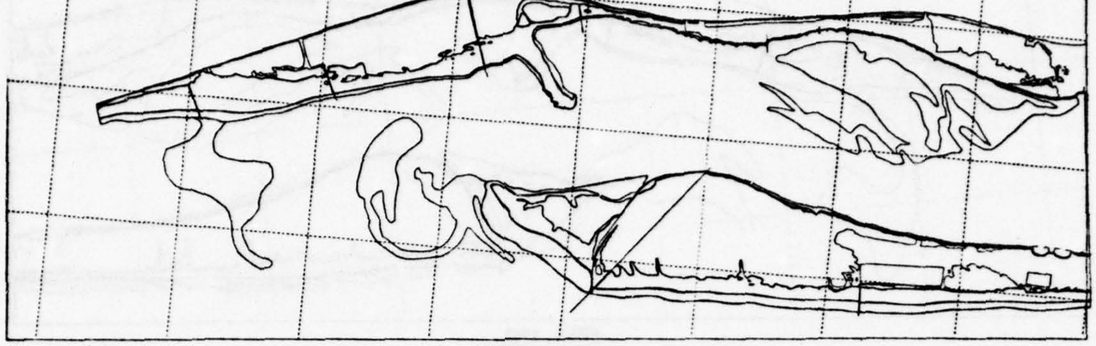


Figure 2. Plots of Fire Island Inlet including all morphologic elements (April 1962-March 1963) (sheet 1 of 6)



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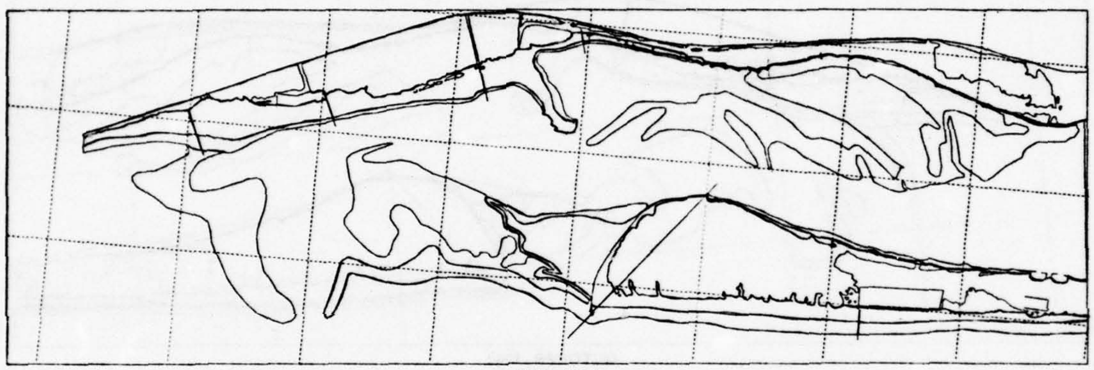
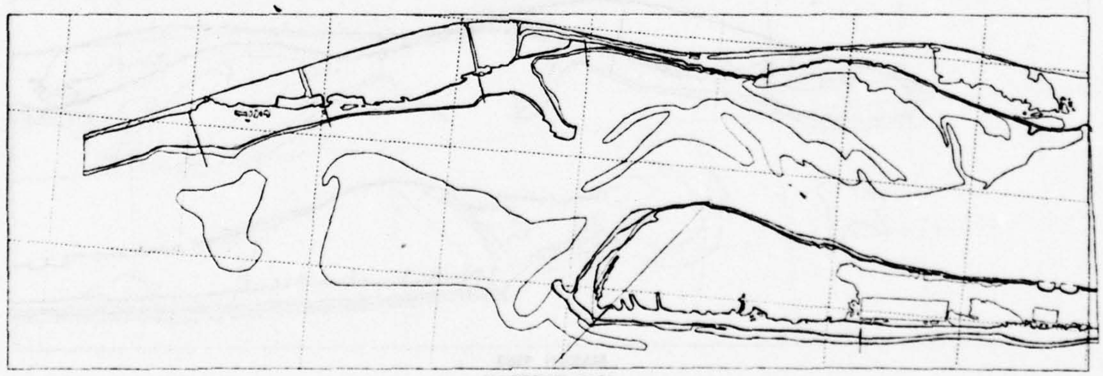


MAY 1964



OCTOBER 1964

Figure 2. (October 1963-October 1964) (sheet 2 of 6)

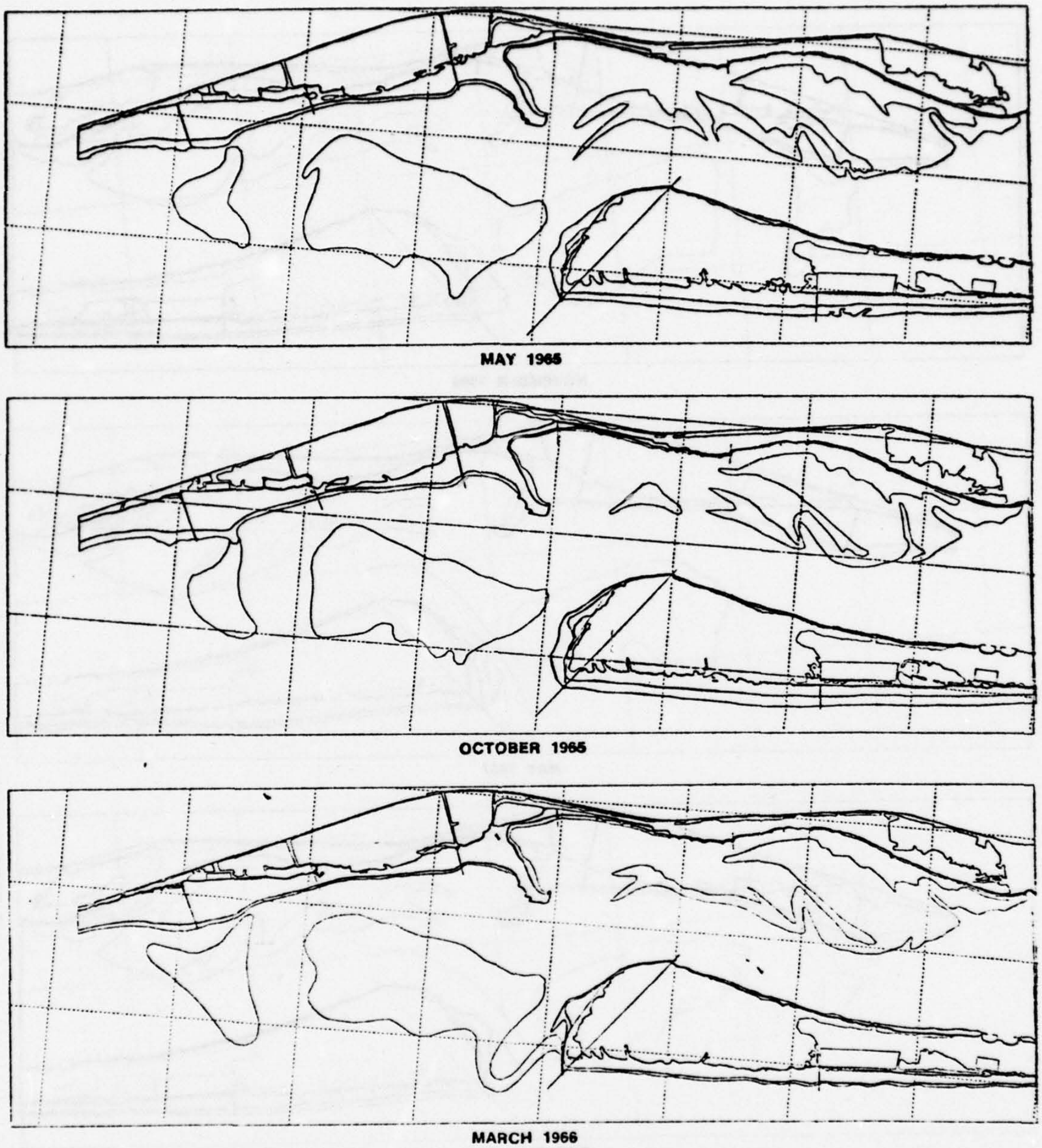


Figure 2. (May 1965-March 1966) (sheet 3 of 6)

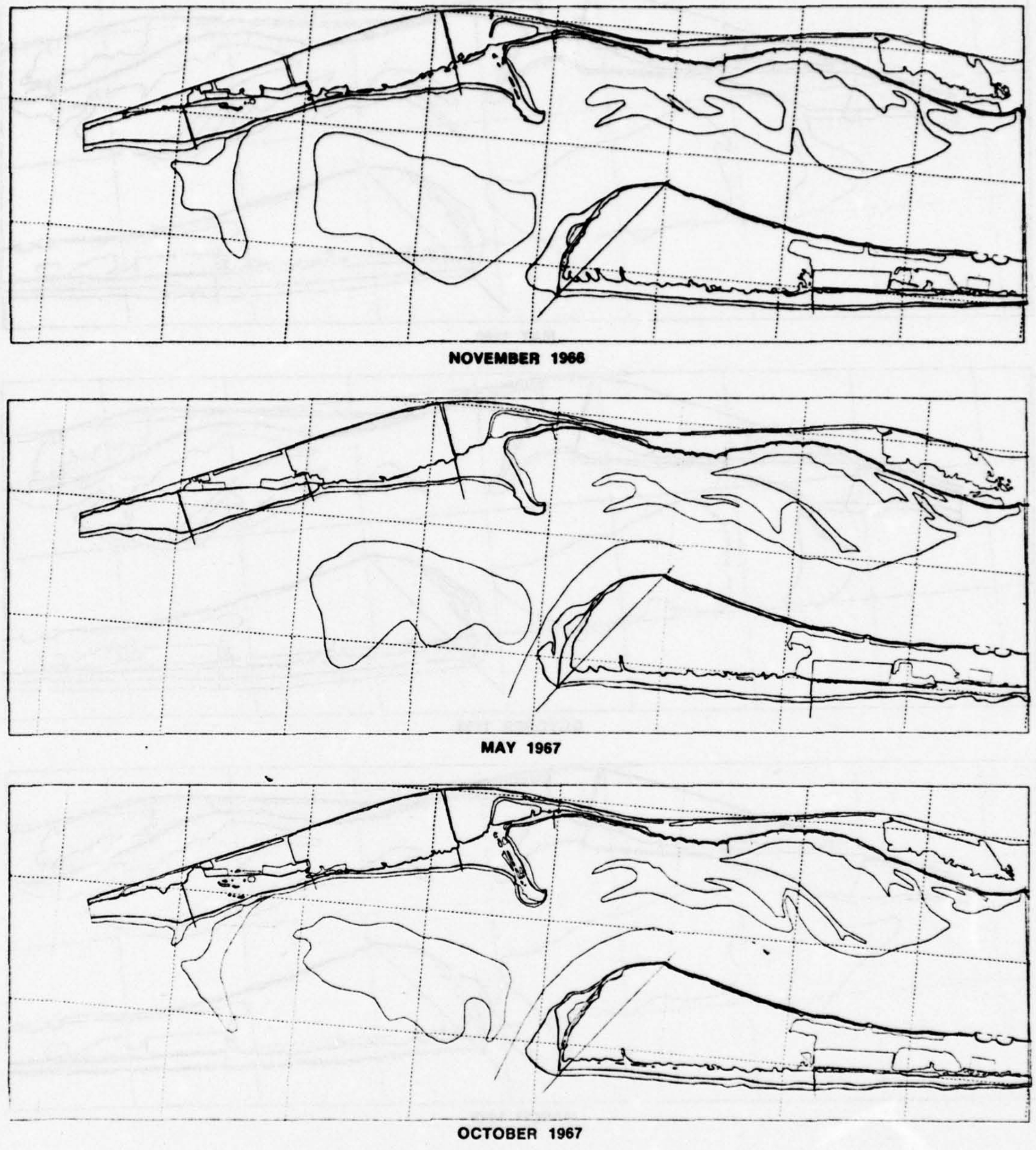


Figure 2. (November 1966-October 1967) (sheet 4 of 6)

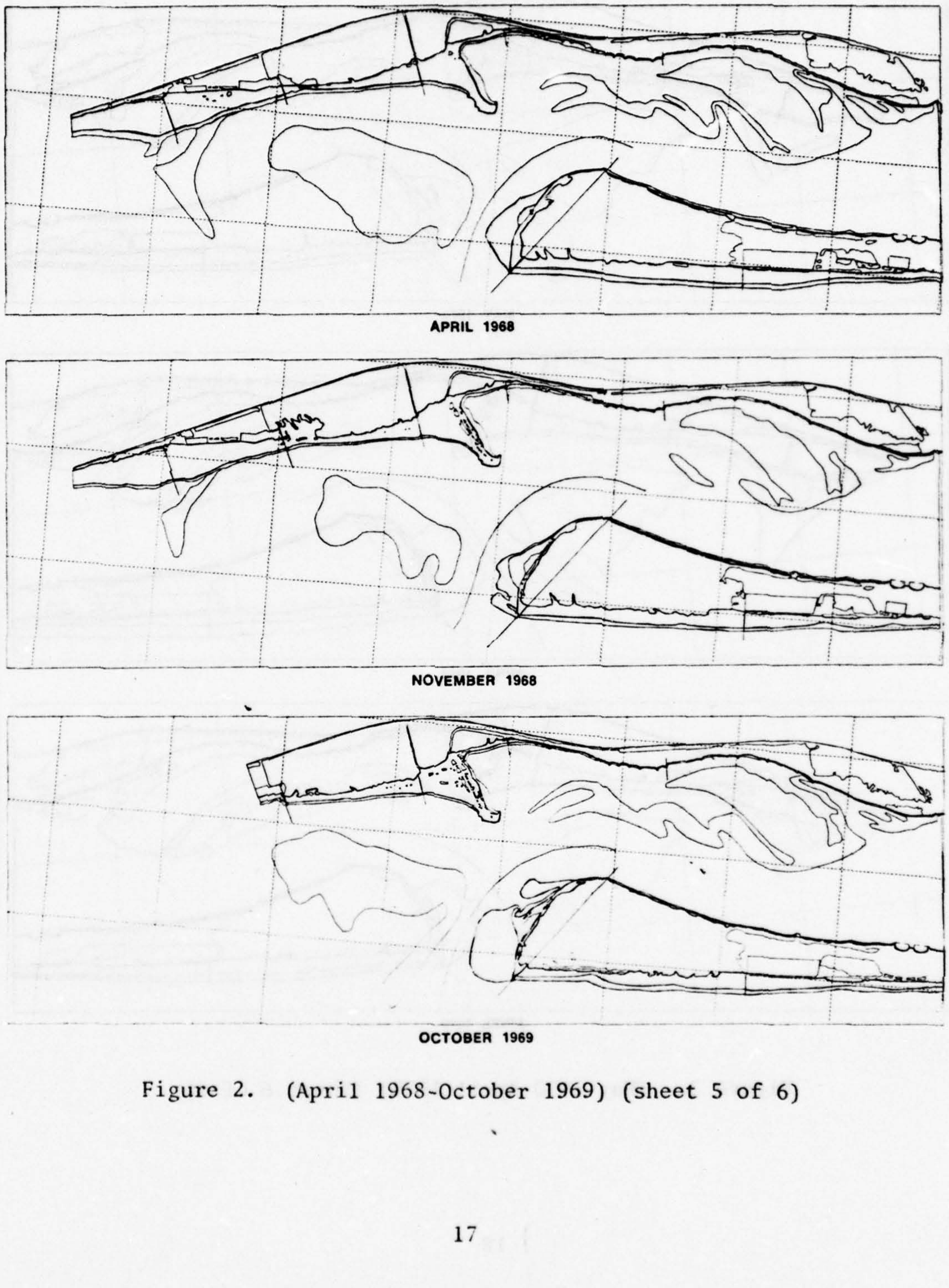


Figure 2. (April 1968-October 1969) (sheet 5 of 6)

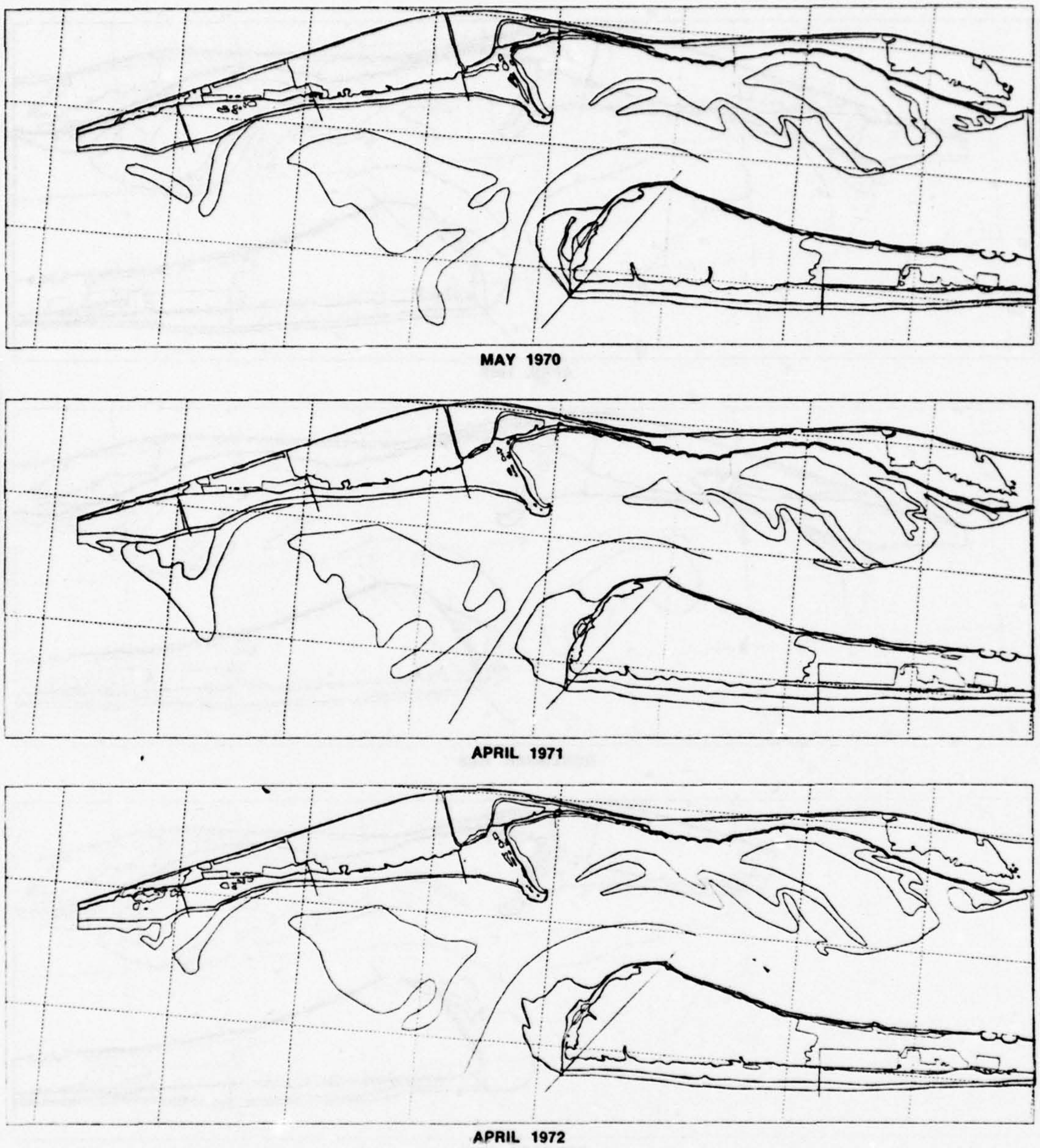


Figure 2. (May 1970-April 1972) (sheet 6 of 6)

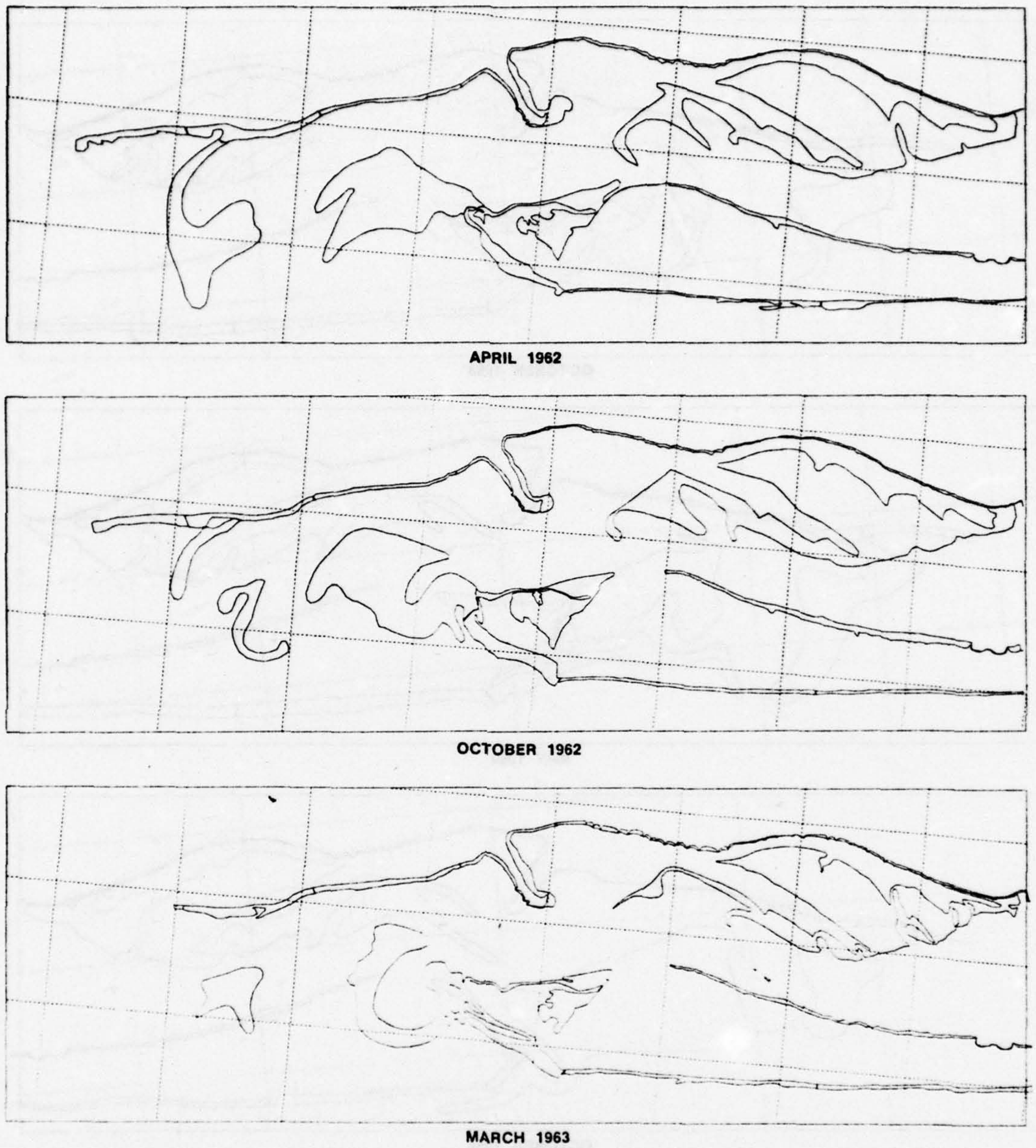


Figure 3. Plots of shoals and foreshore beach areas (April 1962-March 1963) (sheet 1 of 6)

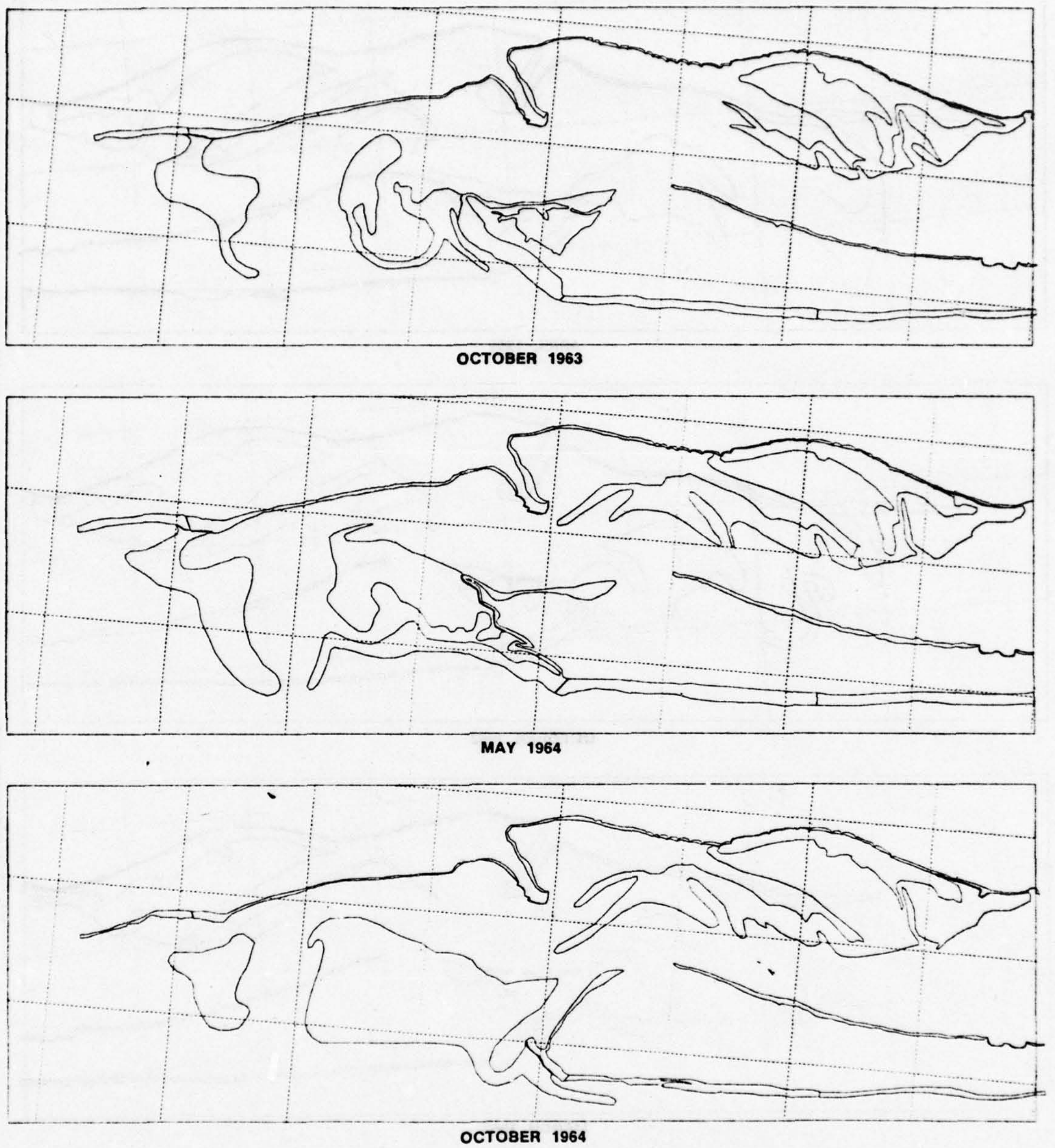


Figure 3. (October 1963-October 1964) (sheet 2 of 6)

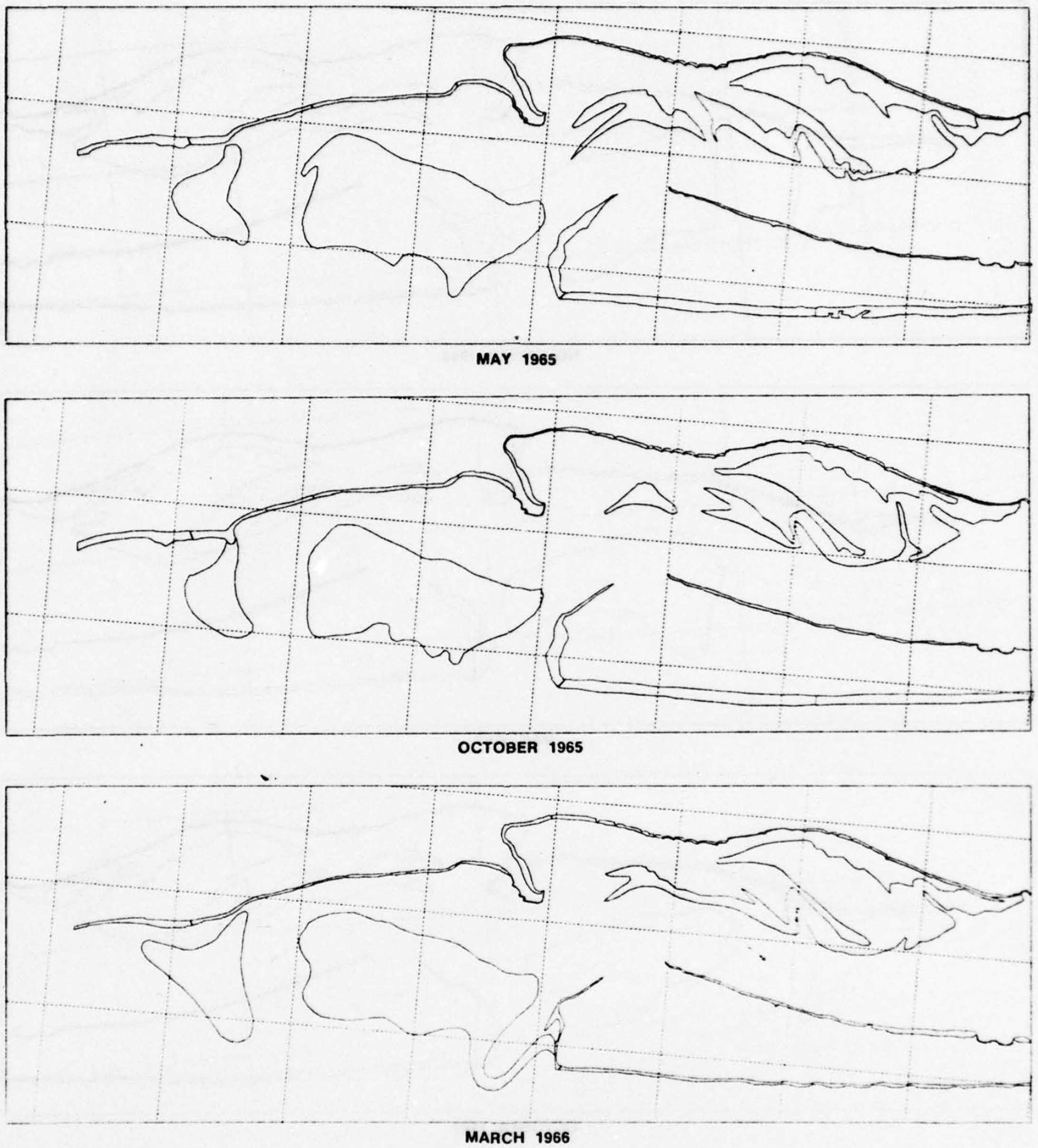


Figure 3. (May 1965-March 1966) (sheet 3 of 6)

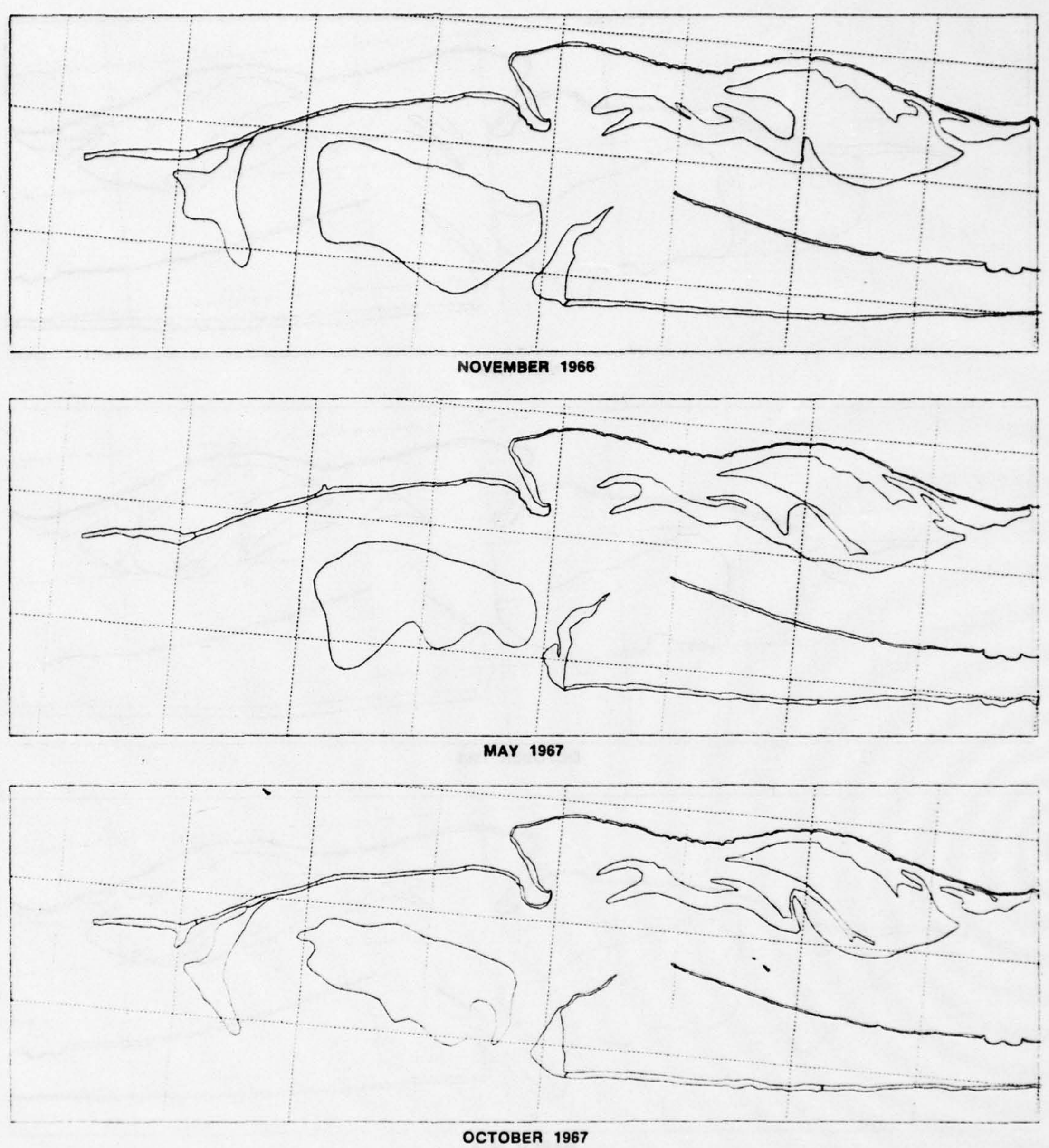


Figure 3. (November 1966-October 1967) (sheet 4 of 6)

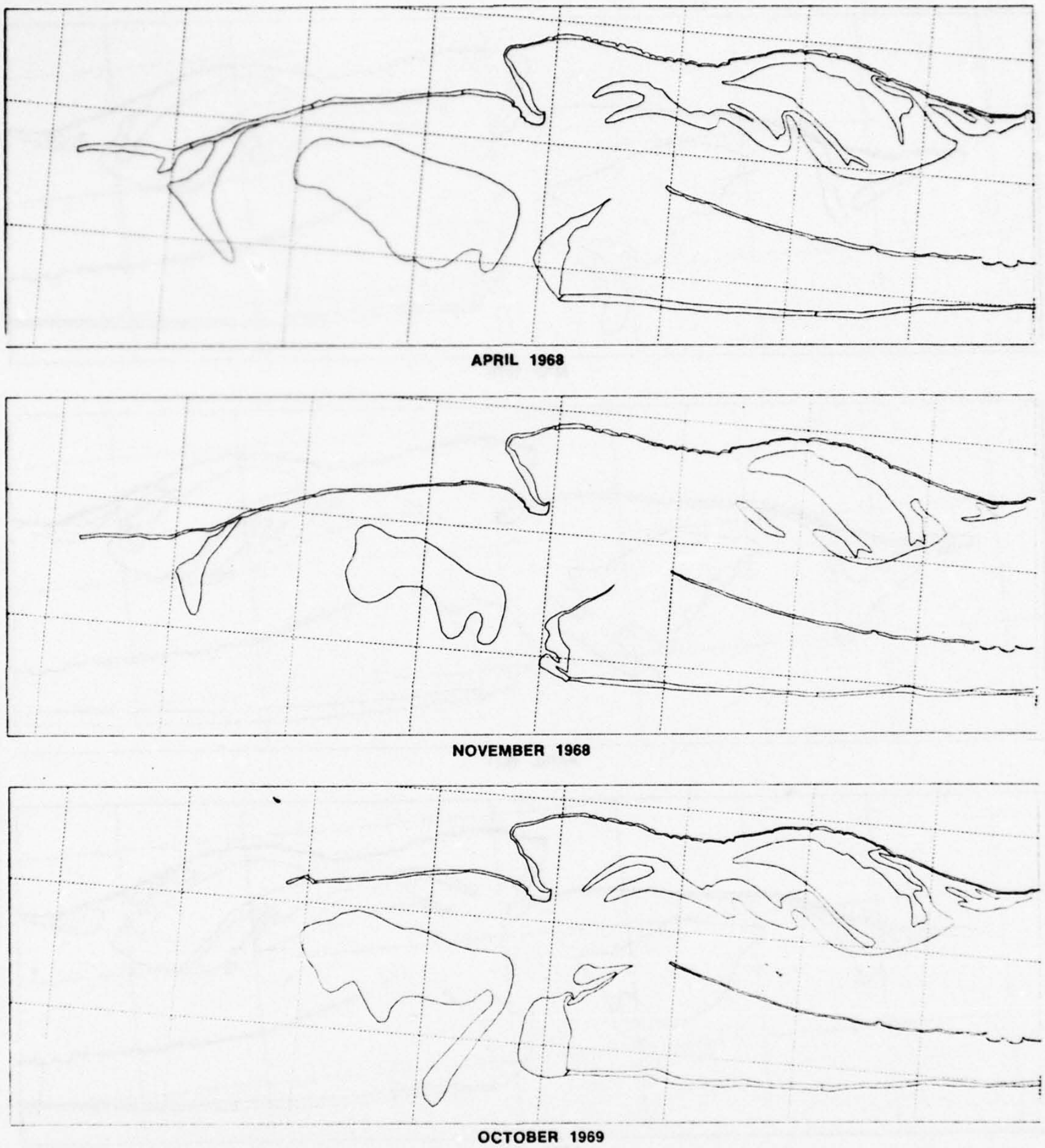


Figure 3. (April 1968-October 1969) (sheet 5 of 6)

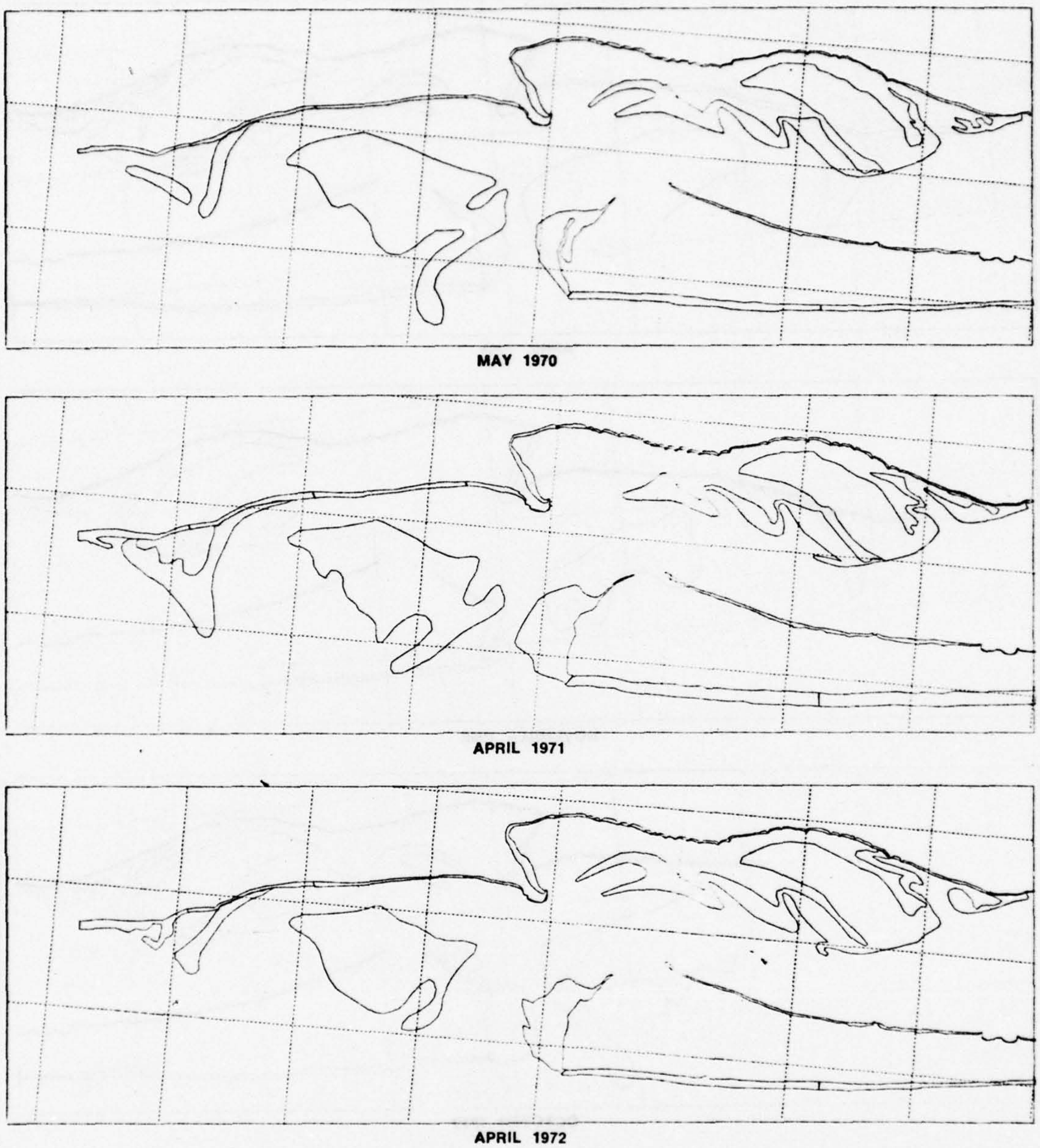


Figure 3. (May 1970-April 1972) (sheet 6 of 6)

19. Overplots provide a convenient way to view all location occurrences of any feature. The positions of the tidal deltas and the spit on all mosaics are overplotted in Figure 4. Three characteristics of the Fire Island Inlet system are evident:

a. On both spring and fall photographs, the main body of the flood tidal delta maintains a relatively constant position. The western end of the flood tidal delta changes in length but not in general position.

b. The secondary channel adjacent to Cedar Beach shoal is relatively stable with respect to both size and location.

c. The size and location of the main channel adjacent to Democrat Point spit are highly variable. Nevertheless, a channel always exists in that general vicinity.

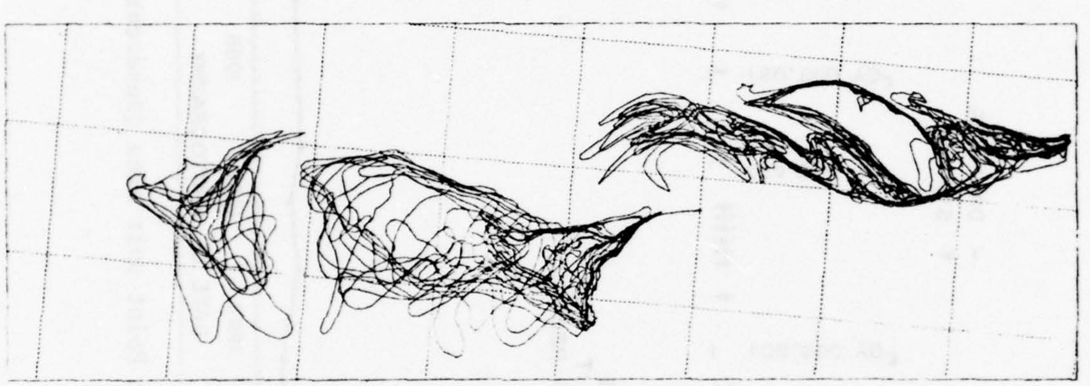


Figure 4. Overplot of all delta and spit locations

Area Calculations

20. Computer-calculated areas of the geomorphic features are listed in Tables 2-18. These data were analyzed and the results are presented below. It must first be emphasized that although these area calculations are characteristic of corresponding changes in volume, they cannot be taken as a quantitative parallel of a volumetric sediment budget. The areas of specific major geomorphic features were first considered as a function of time (Figures 5-10).

21. Democrat Point spit generally exhibits a very slow growth,

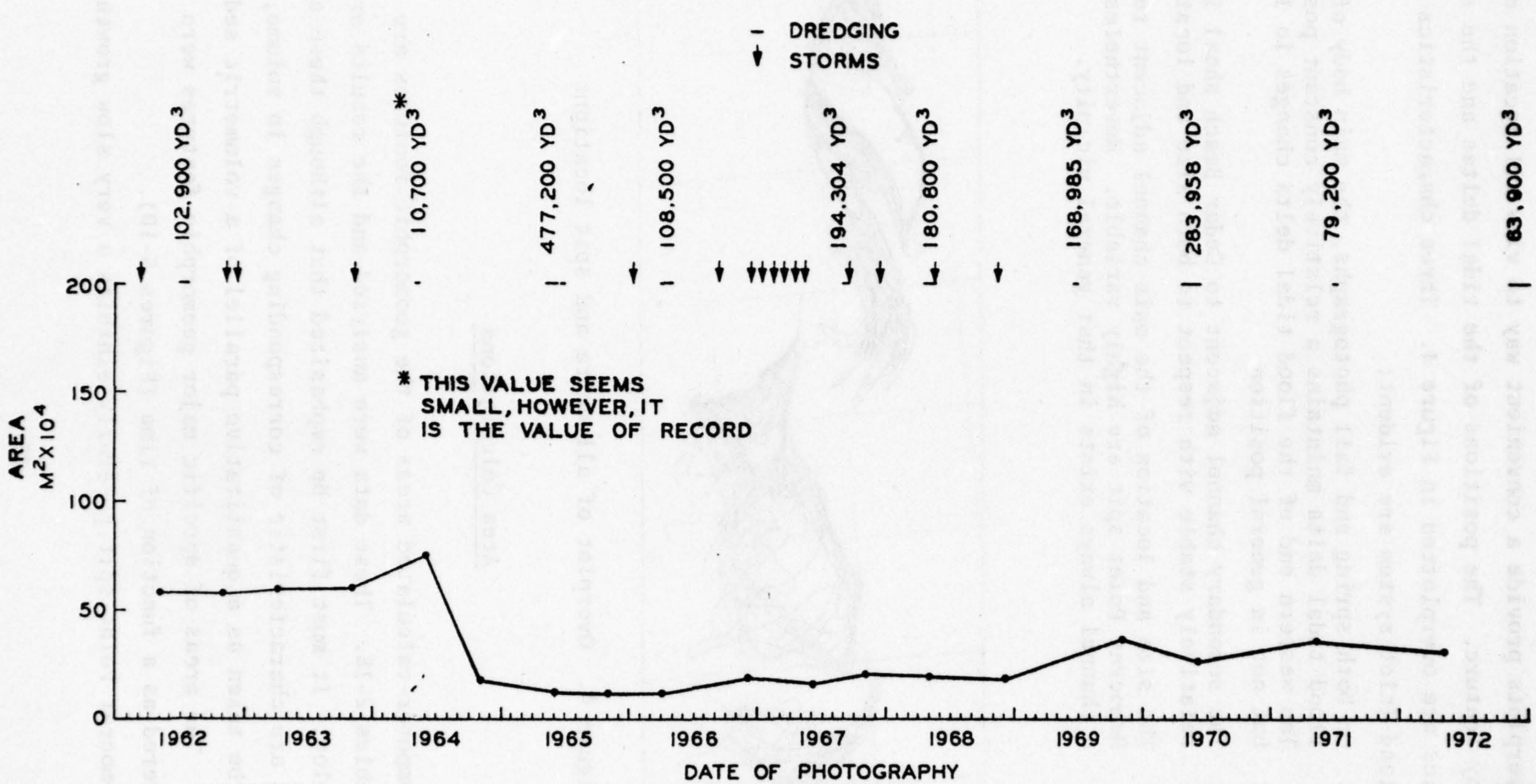


Figure 5. Democrat Point spit area (subareas 412 and 512)

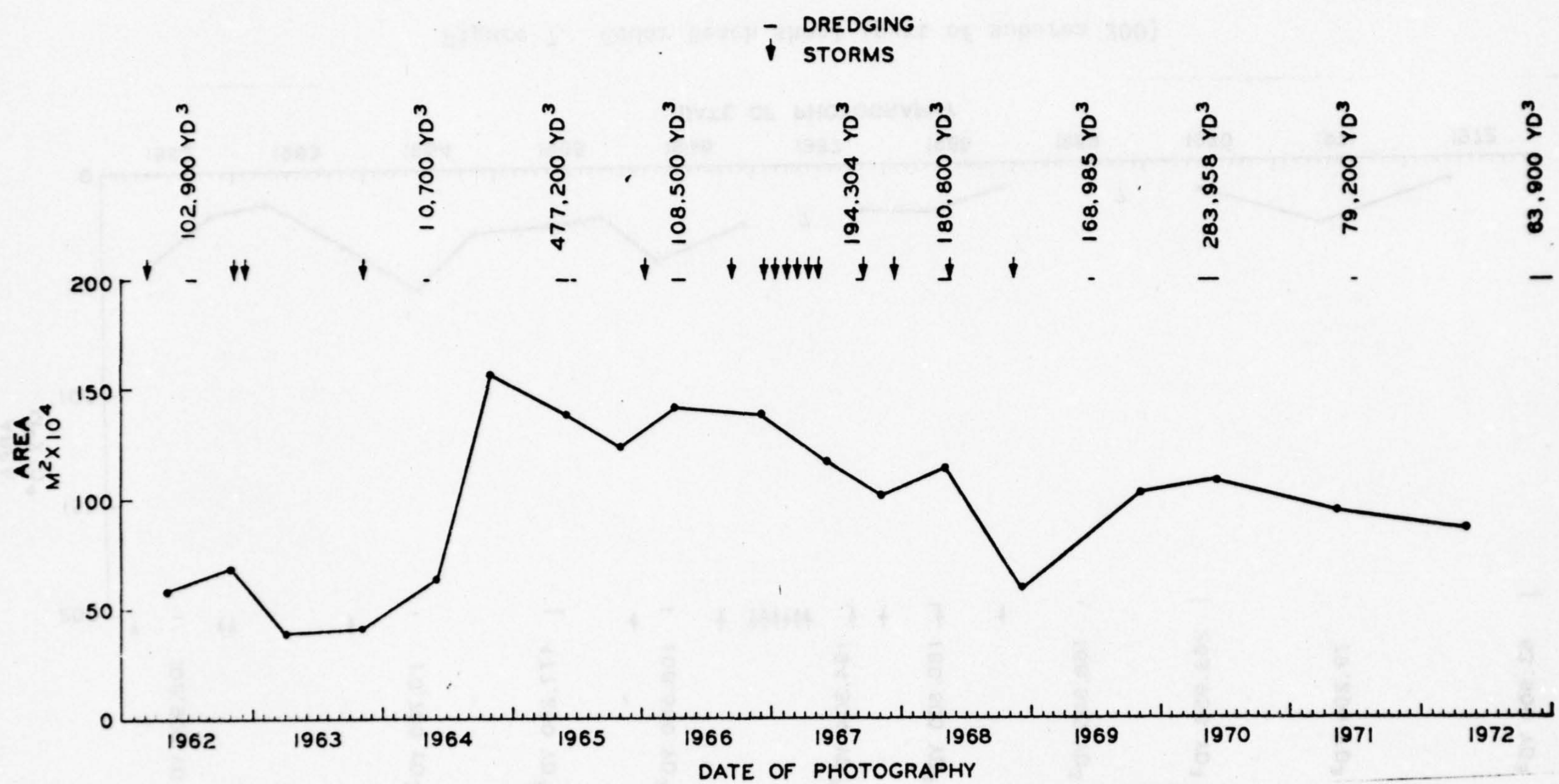


Figure 6. Ebb tidal delta (part of subarea 200)

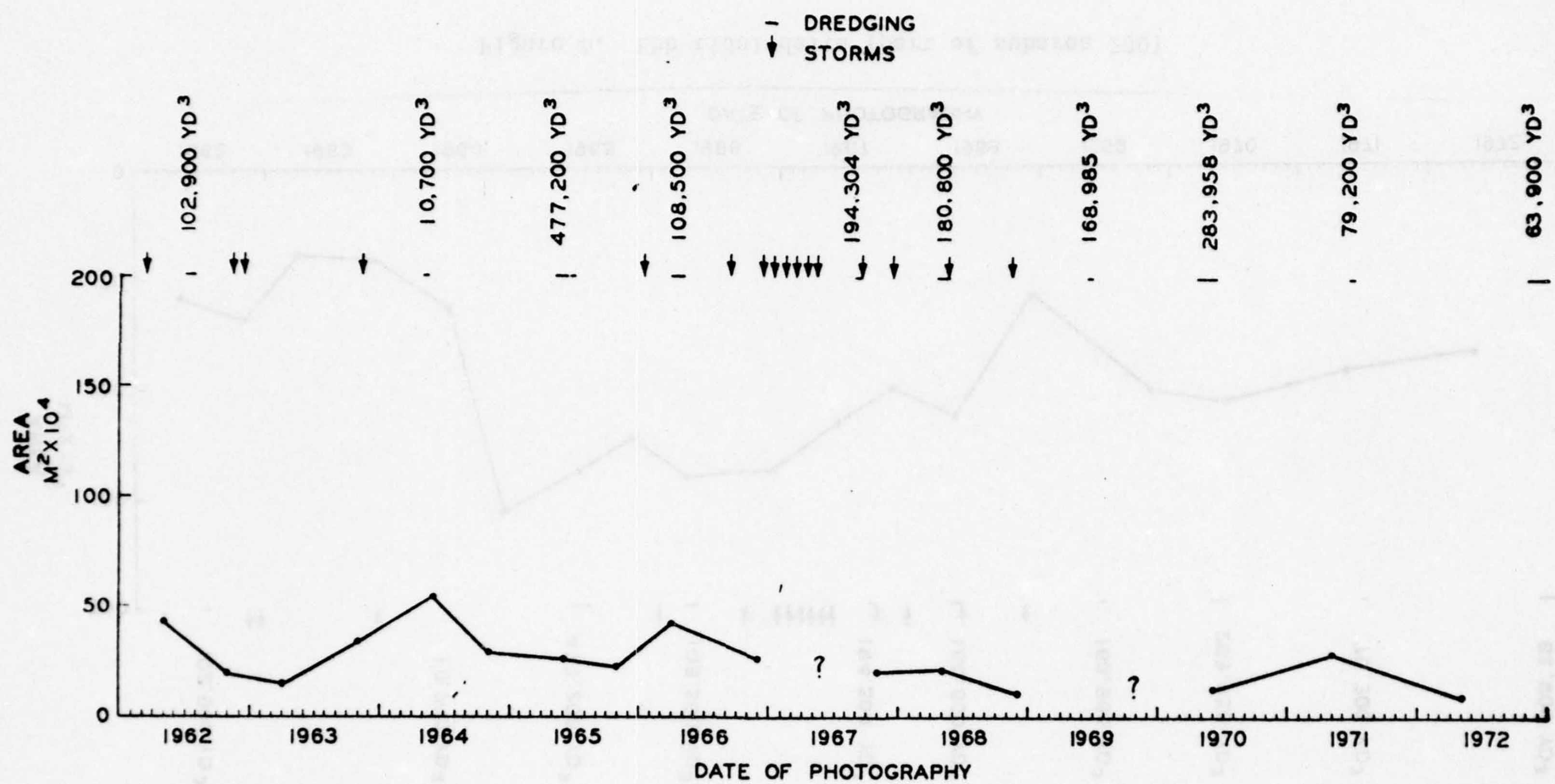


Figure 7. Cedar Beach shoal (part of subarea 200)

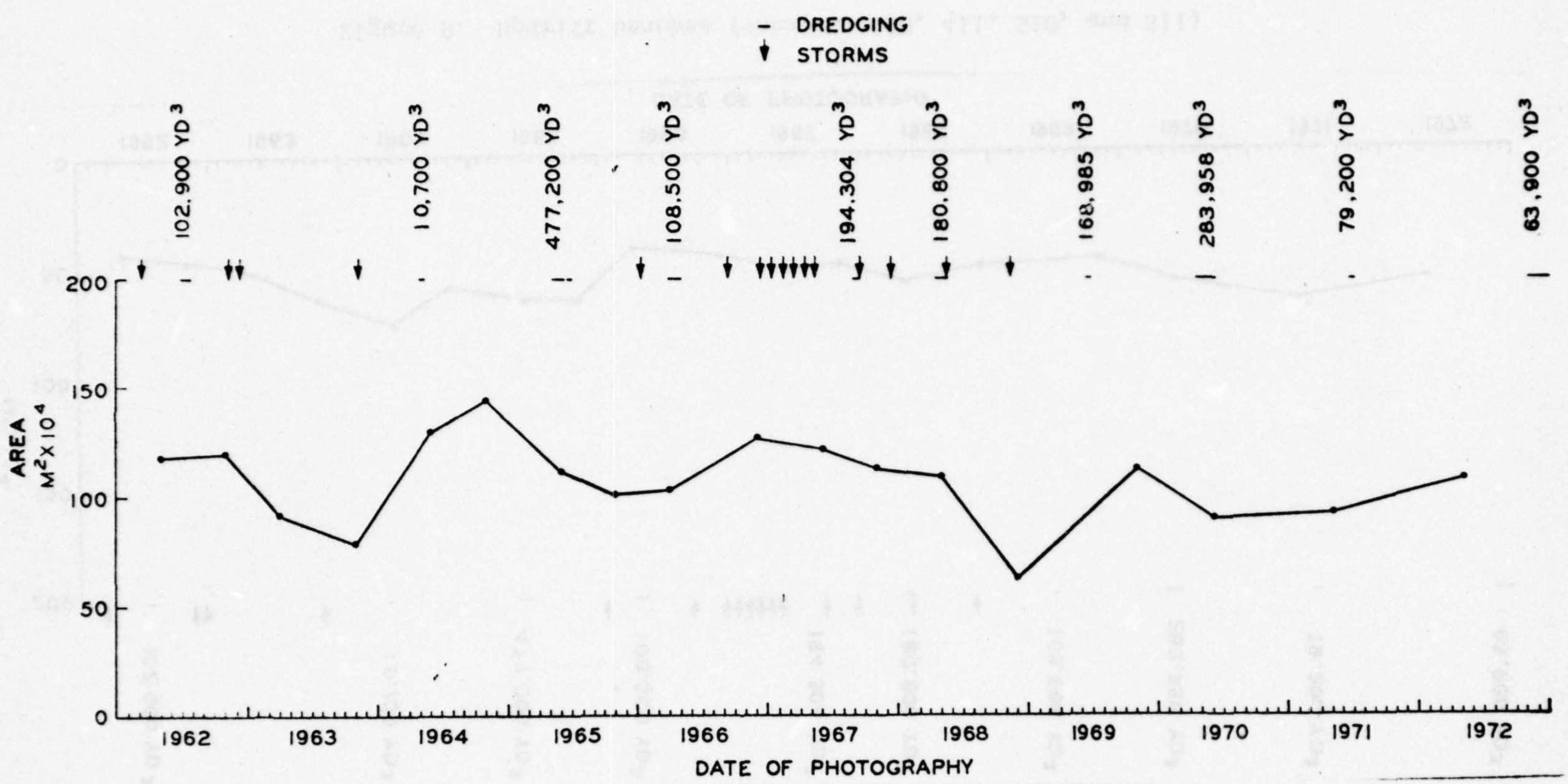


Figure 8. Flood tidal delta (subarea 700)

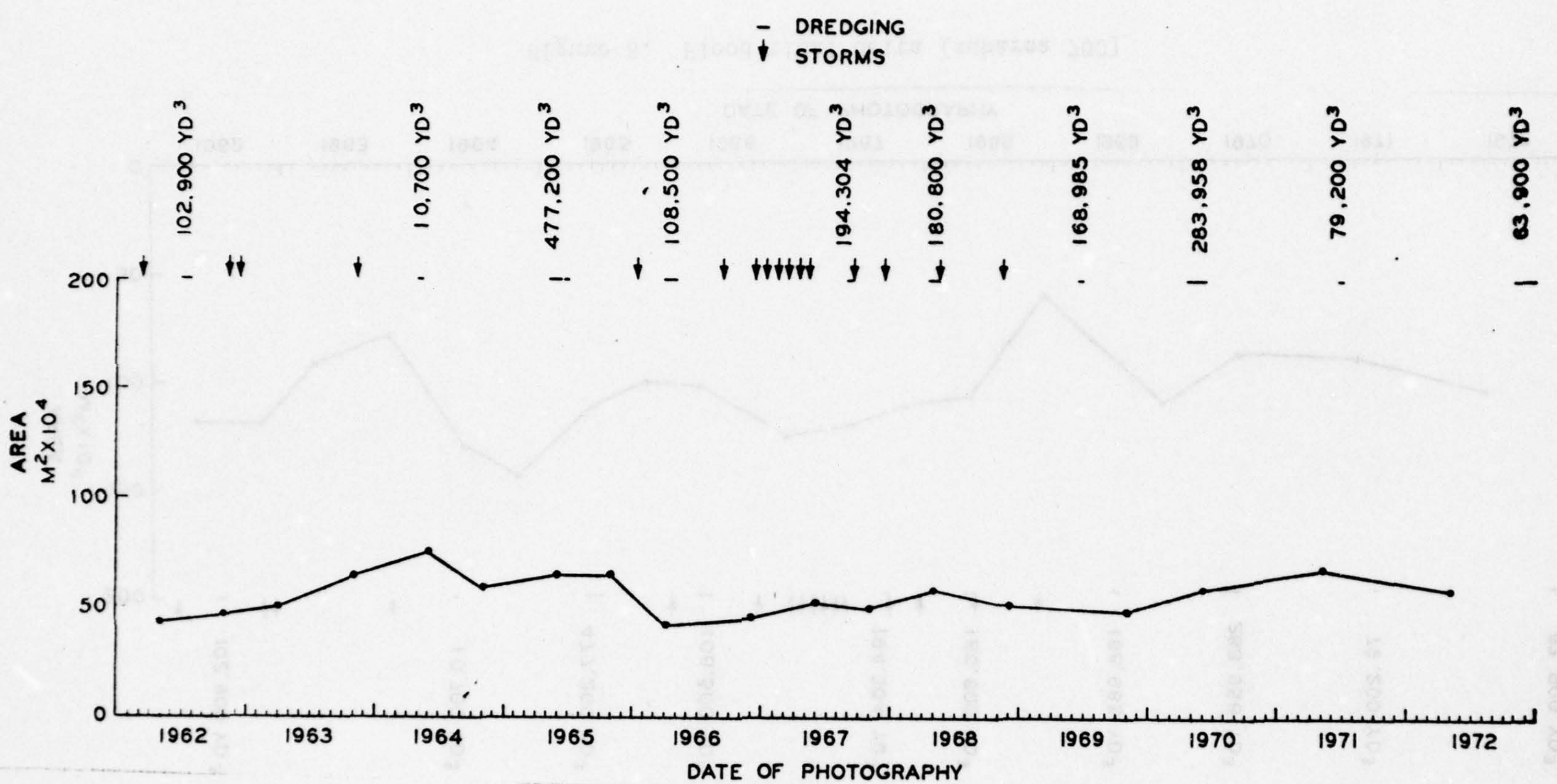


Figure 9. Updrift beaches (subareas 410, 411, 510, and 511)

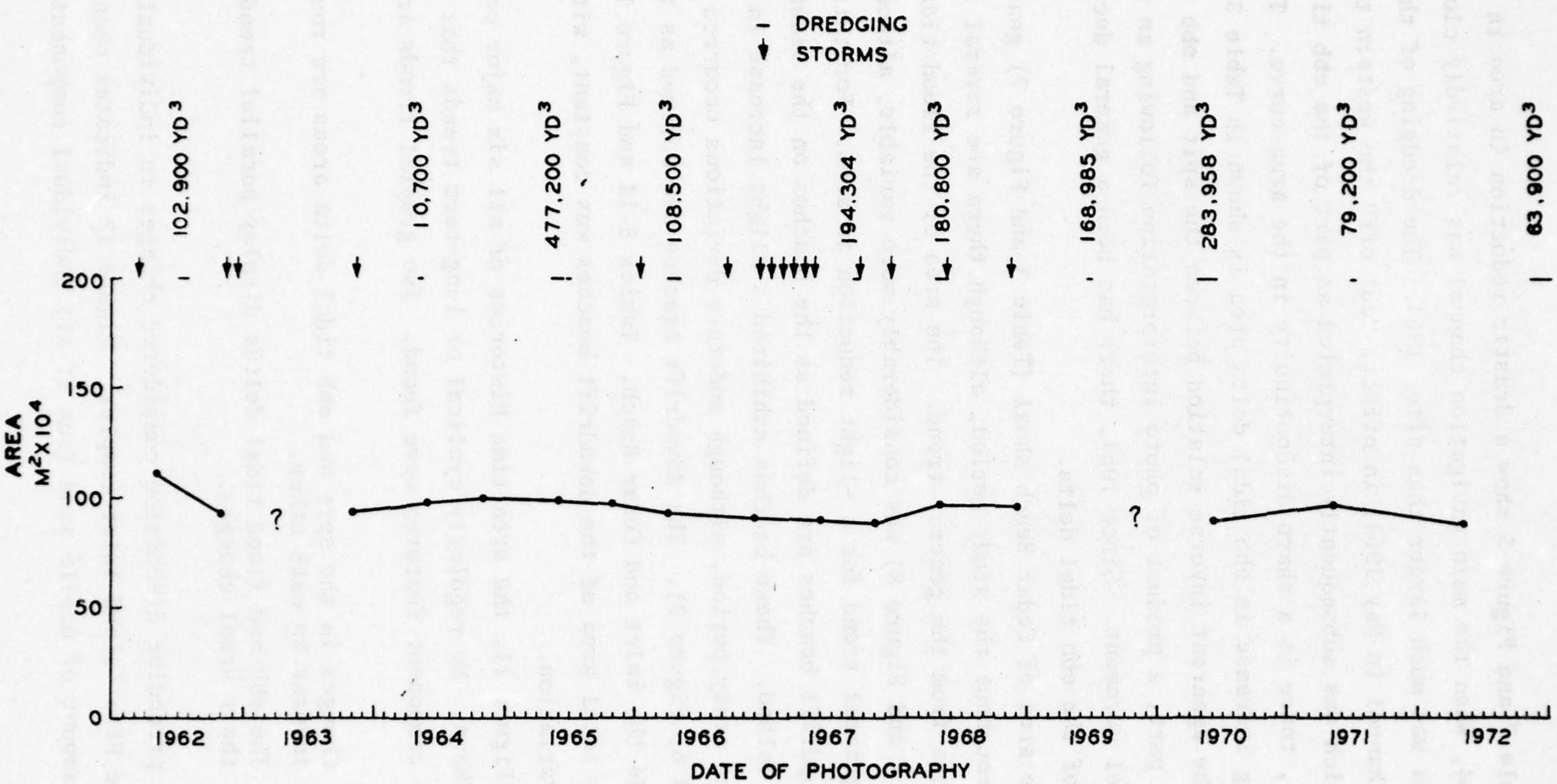


Figure 10. Downdrift beaches (subareas 413, 420-424, 513, and 520-524)

although Table 7 and Figure 5 show a drastic reduction in area in 1964. Prior to 1964, when the main navigation channel was relatively clogged, the spit area was much larger than after 1964. The dredging of the main navigation channel in May 1964, in effect, "cut off" the western tip of the spit, which was subsequently interpreted as part of the ebb tidal delta. Thus, there is a sharp discontinuity in the area curve. The corresponding increase in ebb tidal delta area is shown in Table 3 and Figure 6. The apparent inverse relation between the spit and ebb tidal delta is, in part, a product of photo interpretation following an artificial channel movement. Since 1964, there has been a general decrease in the size of the ebb tidal delta.

22. The area of Cedar Beach shoal (Table 3 and Figure 7) generally decreased throughout the study period, although there are several short term deviations from the general trend. The area of the flood tidal delta (Table 4 and Figure 8) was considerably more variable, although there was a general trend for a slight reduction in area. For this report, the updrift beaches are defined as the beaches on the seaward side of Fire Island. These beaches exhibited a slight increase in area throughout the study period, although moderate deviations occurred (Tables 5 and 6, Figure 9). The downdrift beaches are defined as those beaches inside the inlet and Cedar Beach. Tables 8-14 and Figure 10 show that the total area of the downdrift beaches was constant, with very little variation.

23. In Figure 11, the area time histories of all six major components are shown. No regularly cyclical or long-term trends that relate to all component features were found. Two general trends are evident:

- a. Changes in the spit and ebb tidal delta areas are roughly inverse to each other.
- b. The ebb and flood tidal deltas display parallel trends in their areal changes.

24. The preceding discussion considered changes in individual components of the Fire Island Inlet complex. Figure 12 indicates changes in the total amount of mobile sand (sum of all individual components).

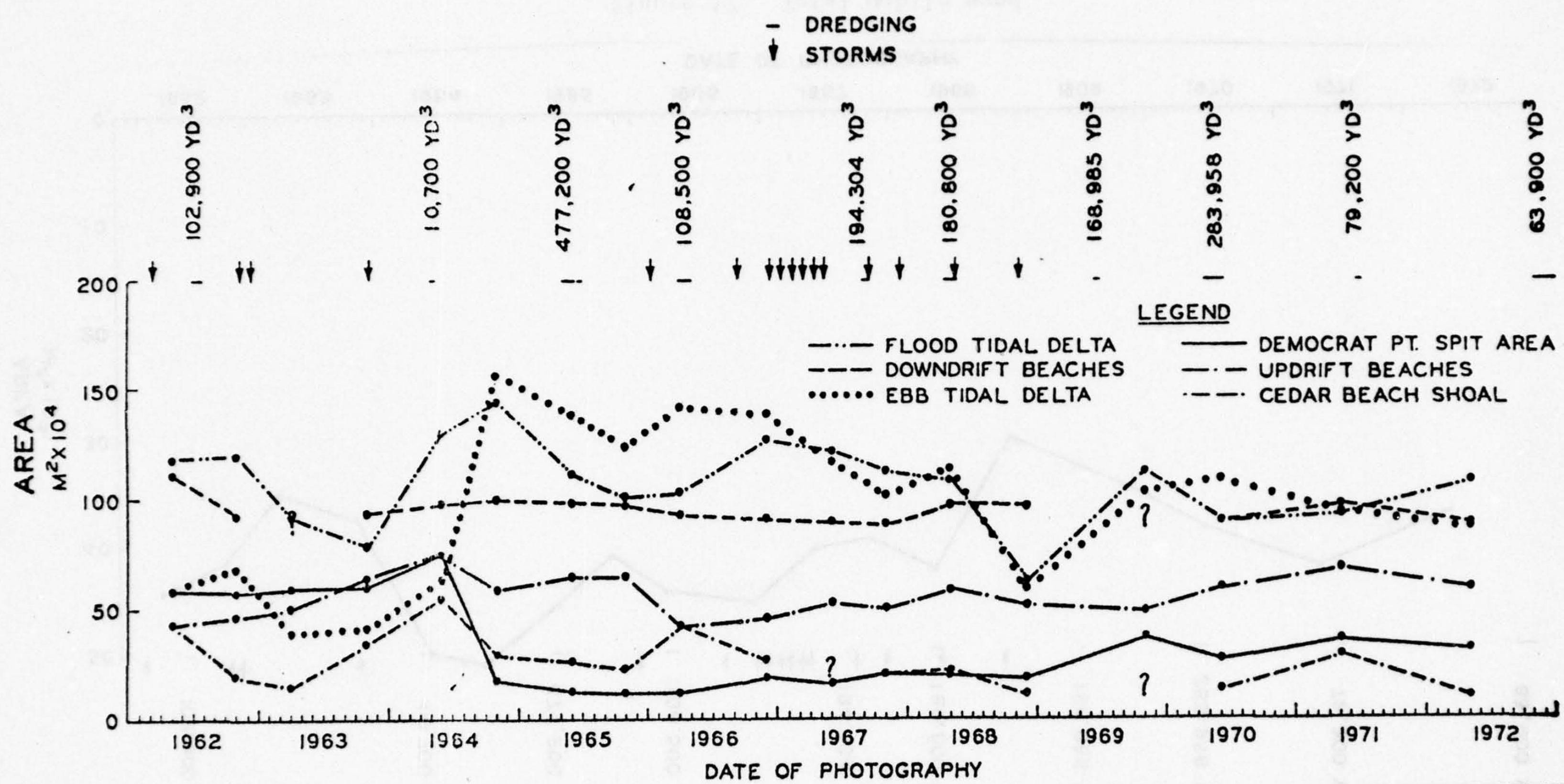


Figure 11. Area of all major features

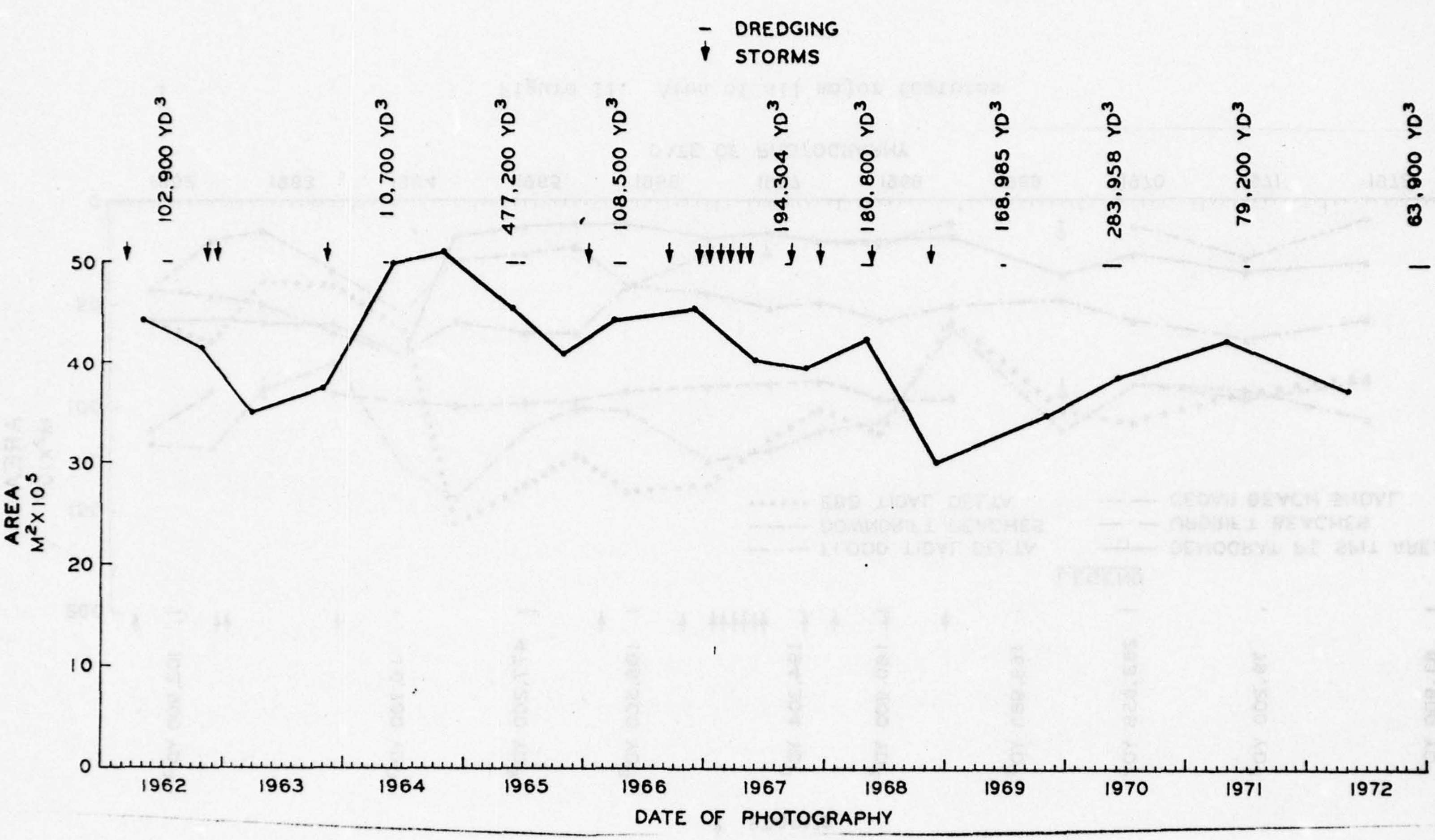


Figure 12. Total mobile sand

Over the 10-year period under study, variations in area of $16 \times 10^5 m^2$ during a 1.5-year period were recorded. This is approximately 33 percent of the total mobile sand. The maximum variation is about $20 \times 10^5 m^2$. Figure 12 indicates a slight decreasing trend in the total mobile sand which may reflect the effect of dredging.

Statistical Analyses

25. Attempts were made to use various statistical techniques to investigate the areal growth-decrease relations between component geomorphic features. The intent was to arrive at an understanding of the extent to which the changes in sedimentological units, e.g. an ebb tidal delta, are dependent on the accretion or erosion of other units within the system. However, due to the very small number of data points and the wide variations in area, the results are not in general significant. This does not imply a lack of physical consistency in changes within the system, but that too few data are available to investigate the relations statistically.

Beach Width Changes

26. Changes in beach conditions are most commonly considered in terms of width. An equivalent to average beach width can be computed if the area of the beach is divided by its length. This was done and the results are presented as Table 19; plots of beach width as a function of time are given in Figures 13a-c. It should be noted that changes in beach widths reported here do not correspond to changes in shoreline position, because such factors as growth of dunes seaward from the dune face (or erosion of the dunes) can lead to a change in beach area independent of changes in shoreface position. Changes in shoreline position are not considered in this report.

27. Figure 13a describes changes in the beaches on Fire Island. One major trend is obvious: beaches exposed to Atlantic Ocean waves (410+510 , 411+511) increased in area for about two years following the

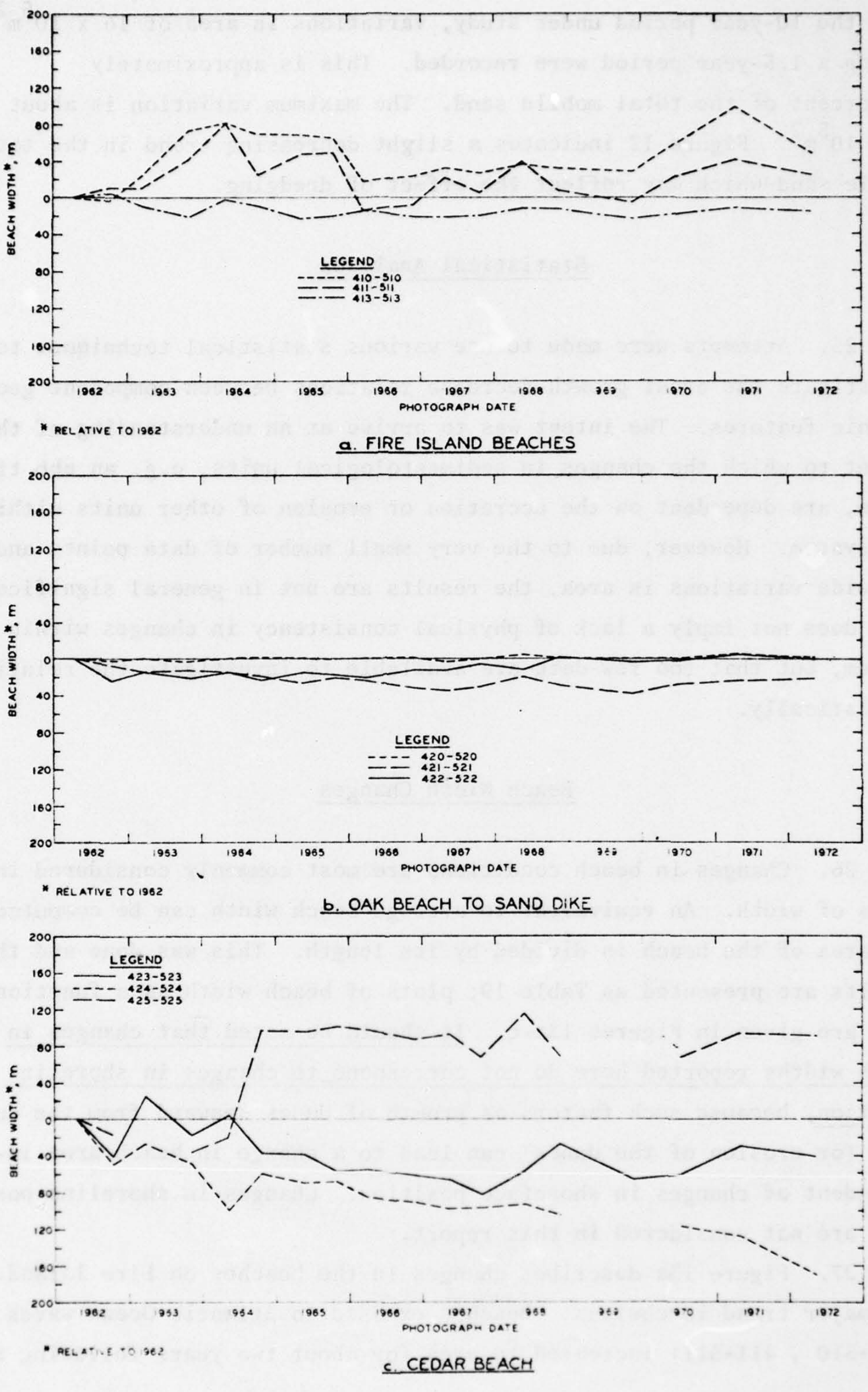


Figure 13. Changes in component areas 1962-1972

March 1962 storm. Subsequently, these beaches narrowed during the 1966-1968 period of prolonged storm activity. Conversely, the beach on the inside of Fire Island (413+513) narrowed slightly in the two years following the March 1962 storm, and subsequently maintained a relatively constant width. In terms of shoreline change this area has undergone fairly severe shoreline recession.

28. Figure 13b describes changes in Oak Beach (from the bridge to the sand dike). The easternmost segment appears to have undergone no change (420+520), probably because the beach is so narrow and steep that its area was close to the expected error of photo interpretation. The changes in width of the beach segment at the sand dike (422+522) cannot be taken to be reliable because the sand dike beach has no "width" in the normal sense of the term, (i.e., shoreface to dune scarp). Although the active sand width has decreased slightly, this entire area has prograded significantly. The area of this beach segment, however, reduced slightly immediately following the March 1962 storm, remained essentially constant until the end of the 1966-1968 storm period, then returned to its previous area. The intervening segment (421+521) appears to have undergone a slight continual decrease in width since the 1962 storm, possibly indicating that some sand is stored in the interior channels during major storms, only to be released in poststorm equilibration. The slight increase in area during the 1966-68 storm period corresponds to such a trend.

29. Figure 13c shows that the western segment of Cedar Beach (425+525) lost a moderate amount of width during the year following the 1962 storm. During the last half of 1964, however, a major accretion occurred (primarily in the backshore portion of the segment), and the width remained essentially constant after that time. The increase in 1964 is due primarily to artificial beach nourishment with materials from the channel dredging. The critical segment of Cedar Beach (424+524) is in the lee of Cedar Beach shoal and the ebb tidal delta. This segment continuously narrowed throughout the study period, as did Cedar Beach shoal (Figure 7). The eastern segment of Cedar Beach (423+523) fluctuated in width for about two years after the 1962 storm,

then narrowed until 1968, and finally widened through 1972. There appears to be some progradation of the shoreline position, coupled with the decrease in beach width shown here. No strong correlation between beach and ebb tidal delta areas can be discerned from the data, however (compare Figures 6 and 13c).

Shoal Location and Stability

30. In order to evaluate the stability of ebb and flood delta and Democrat Point spit locations, an 80-ft grid was superimposed on each of the plots showing shoal positions, and those grid points located within the shoal or spit areas of interest were identified. Each grid point was input to a computer program which compiled the frequency with which each grid point was identified as a shoal or channel area. These frequencies were replotted on the grid and contoured. Separate plots were made for the period after dredging the channel between the ebb tidal delta and Democrat Point spit (Figure 14a) and for the entire study period (Figure 14b).

31. The results indicate that the central mass of the flood tidal delta is very stable and the seaward end is less stable. This seaward ebb spit on the flood tidal delta is generally confined to the same area, but its areal extent and shape vary considerably. The secondary channel area between the Cedar Beach shoal and the ebb tidal delta appears stable.

32. The main navigation channel (between the ebb tidal delta and Democrat Point) and the ebb tidal delta are unstable. The main channel is somewhat more stable since dredging (Figure 14a). Prior to dredging it was recognized as shoal more than 50 percent of the time, after dredging it was identified as shoal only 25-50 percent of the time. The ebb delta shape is still highly variable. Prior to dredging, the spit and ebb delta were frequently difficult to separate.

33. Although the frequency of occurrence analysis was not performed for other morphologic components of the inlet and adjacent land areas, it would appear a valid way to investigate the stability of beach and dune areas.

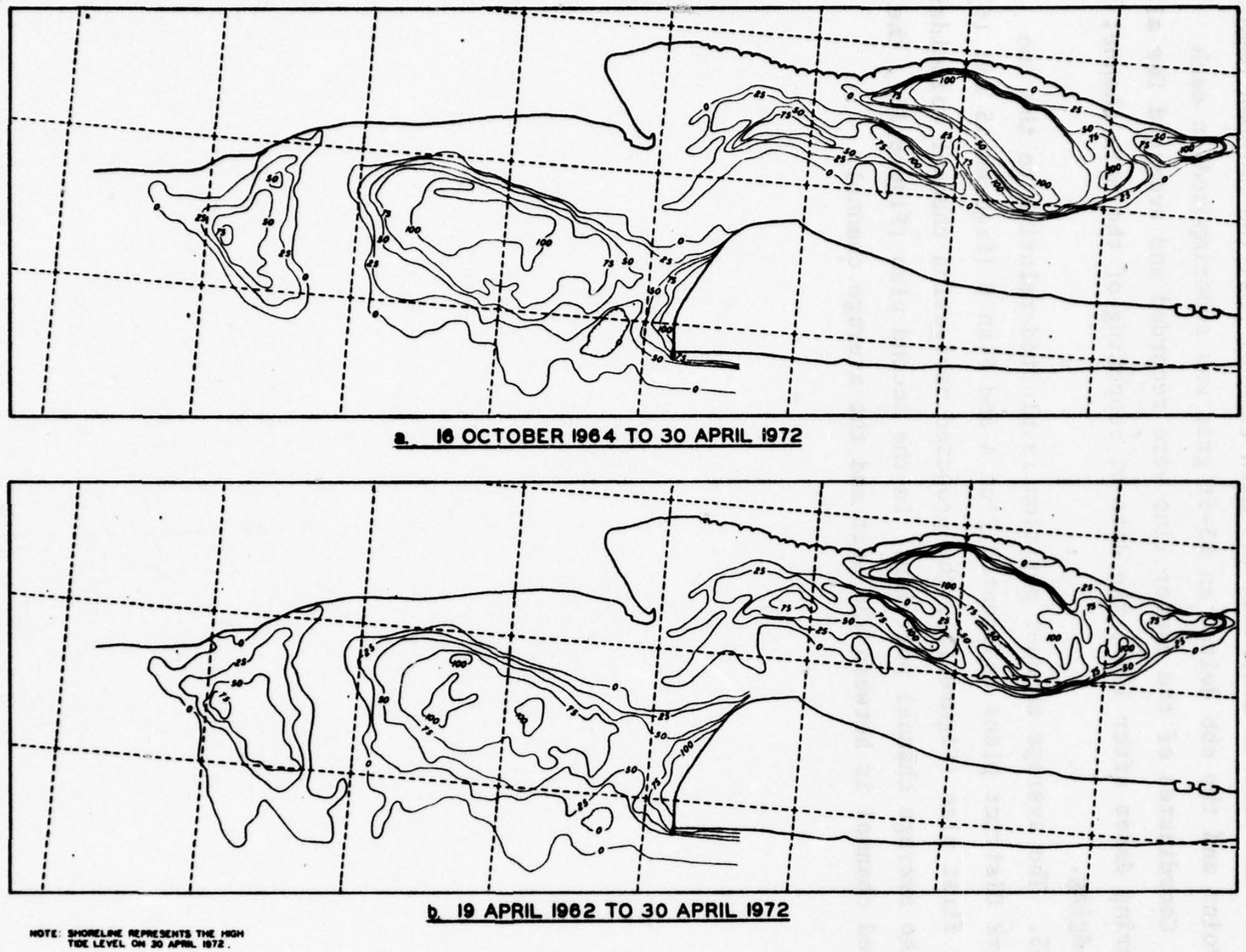


Figure 14. Frequency of tidal delta occurrence

Average Channel Location

34. In order to ascertain the main channel position between Democrat Point and the ebb delta, an 83-ft grid was superimposed on each plot. Coordinates of the center line were recorded and averaged for all postspring dates after 1964, the date of reopening of the main channel by dredging.

35. The average channel position is plotted relative to the two New York District plans designated Plan A and Plan B (Figures 15 and 16). In the first plan (Figure 15), the proposed navigation channel coincides with the average channel position. In the second plan (Figure 16), the proposed channel is between the spit and the average channel.

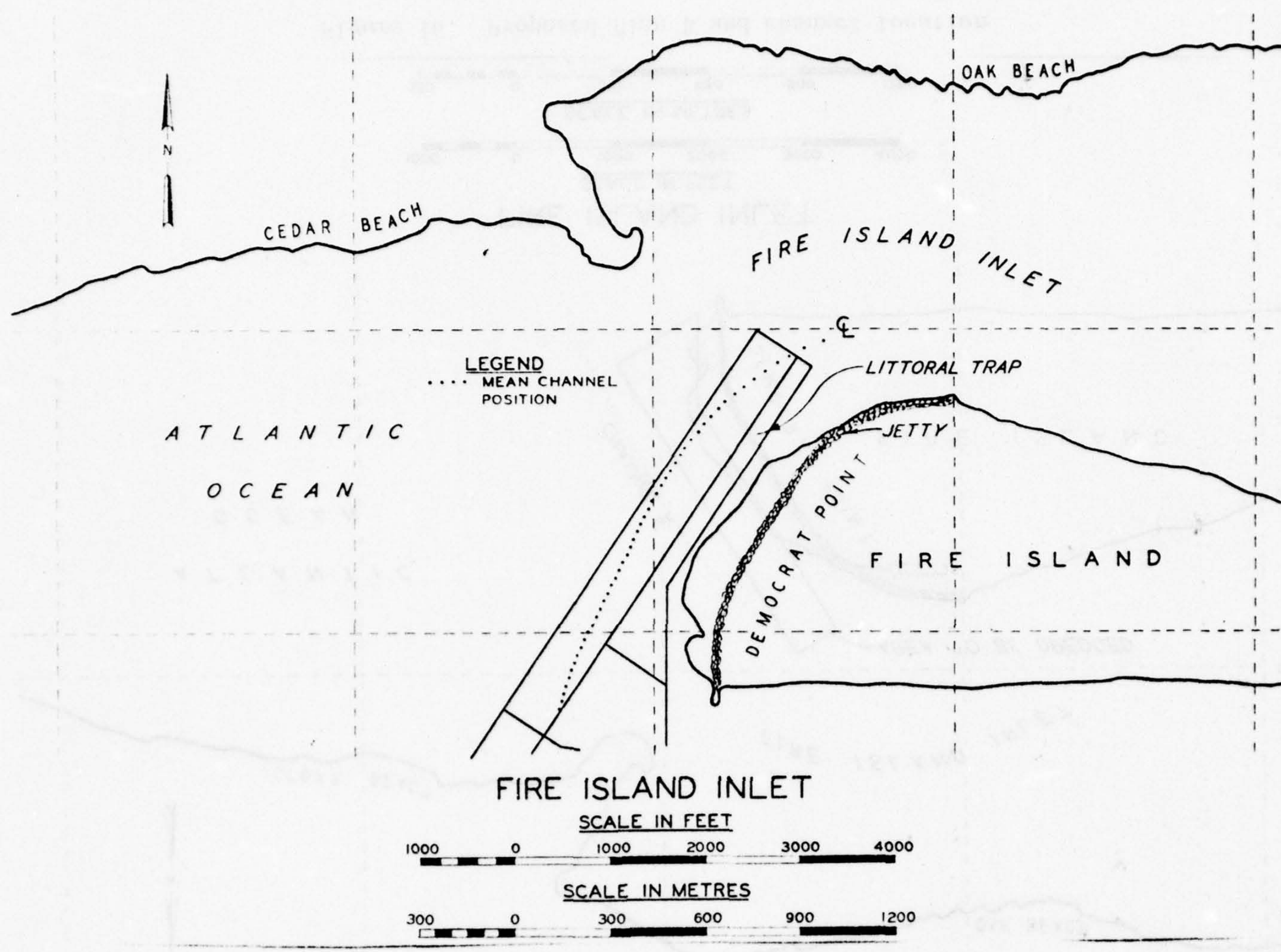


Figure 15. Proposed Plan A and channel location

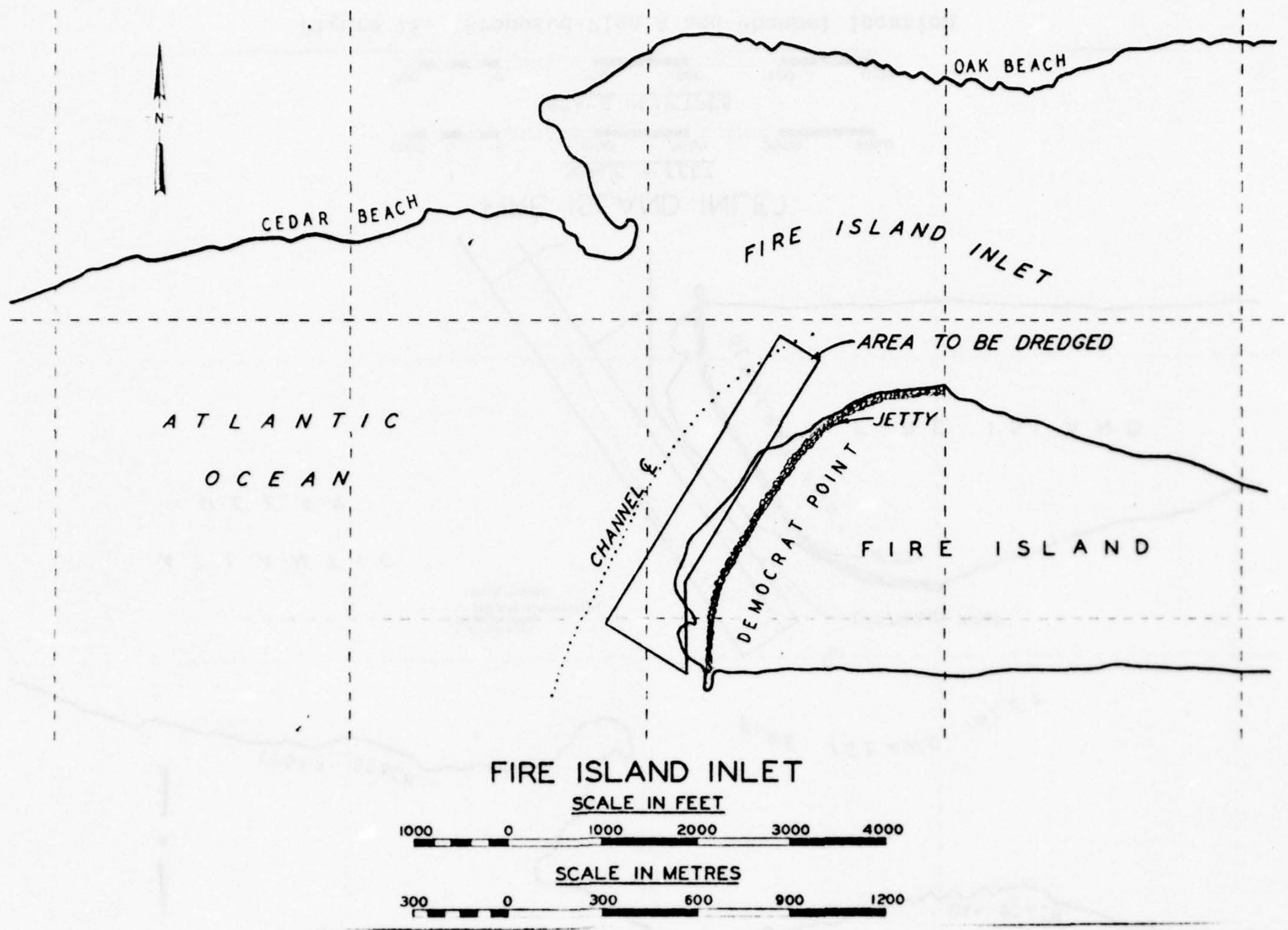


Figure 16. Proposed Plan B and channel location

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Geological Implications

36. One primary geological implication from the study must be that the amount of sand in the inlet system, as measured by the areas of beaches, dunes, and shoals, has not remained constant through time. This is reasonable if yearly variations in longshore drift are considered. More material may be transported into the inlet than can be removed or bypassed, resulting in storage of sand in the system, which in periods of lower net longshore energy may be transported out of the system. It is apparent that the ebb and flood tidal delta areas grow proportionately, not inversely, and sediment appears to be stored in the inlet system during major storms and removed during calmer periods.

37. The area of the ebb tidal delta has exhibited a decreasing trend since 1964. This is undoubtedly due to the artificial bypassing of sand by channel dredging and the resultant pumping of sand to the beach west of Cedar Beach.

Photogrammetric Technique: Sources of Error

38. The technique demonstrated here can be used rapidly to extract extensive areal and locational data from aerial photography. Undoubtedly the method is more accurate in dealing with subareal features with more easily definable boundaries (such as dune areas); however, the method does appear to provide reasonably accurate locations and shapes of subaqueous landforms.

39. Sources of possible error in the data presented here include:

a. Subjective interpretation of boundaries. The greatest source of error is believed to be the subjective methods used in defining boundaries, particularly of shoals. Photo interpretation relies to a great extent on the observer's application of rigid criteria to consistently define boundaries; however, results can be consistent but inaccurate. Results with the largest potential error are underwater features with gentle slopes. Because the data

used are historic and no control on turbidity or sun angle exists, visual interpretation of the breakpoint in the slope may be inconsistent between photographs because of different depth penetration of light. On the photographs used, the turbidity and sun angle did not appear to vary excessively as can be seen from the consistent estimation of some shoal boundaries; however, their true effect cannot be accurately estimated. Experience would suggest a 10 to 15 percent error in area calculations under these conditions. It should be noted as well that the intent of the project was to estimate shoal positions and areas. Review of the results suggests that the project adequately represented gross scale changes in the system.

b. Digitizing error and photogrammetric error. Previous studies have indicated that errors from digitizing are small compared with other methods of data collection, such as planimetering. Semicontrolled photomosaics likewise are adequate.

Sampling Considerations

40. The data base for this study consisted of 18 photomosaics taken at approximately six-month intervals. With such a coarse sampling interval, it must be stressed that only general trends can be adequately studied. Further, the photographs were often taken to investigate the effects of dredging or storms. However, the data base for Fire Island Inlet is at least as good as that for any other inlet, and it is better than that for most other inlets.

Conclusions

41. The following conclusions can be made:

a. The channel proposed in Plan 1 is most appropriate in terms of matching the average channel location. Since reopening of the channel by dredging in 1964, channel location has been relatively stable, probably due to periodic dredging in the reach between the ebb tidal delta and Democrat Point.

b. The channel proposed in Plan 2 is between the average channel location and Democrat Point. Whether or not this will be a stable channel cannot be evaluated from the information contained herein.

c. The photodigitization technique appears to offer a rapid method for collecting information from sets of aerial photography, reducing the data to a standard output basis and providing both graphical and numerical display of the information. In inlet studies it is very useful in analyzing changes in the areas of specific morphologic components and in indicating spatial patterns of change. It should be noted that the accuracy of the measurements depends in large part upon the quality of field control information. In this study no such control was available. In any future coastal studies involving areal patterns of change over a large site area, the coupling of a program of intense aerial photographic coverage with adequate field control would provide highly accurate measurements of change not obtainable by other means (with reasonable cost).

Table 1

Fire Island Inlet Aerial Photography Employed in Study

Date	Original Scale	Enlarged Scale	Film Type	Source
19 Apr 62	1:18,000	1:9,000	B/W	LKBI
12 Oct 62	1:16,000	1:8,000	B/W	LKBI
14 Mar 63	1:12,000	1:12,000	B/W	LKBI
31 Oct 63	1:16,000	1:8,000	B/W	LKBI
7 May 64	1:20,000	1:10,000	B/W	LKBI
16 Oct 64	1:19,000	1:9,500	B/W	LKBI
14 May 65	1:16,000	1:8,000	B/W	LKBI
25 Oct 65	1:19,000	1:9,500	B/W	LKBI
27 Mar 66	1:19,000	1:9,500	B/W	LKBI
14 Nov 66	1:20,000	1:10,000	B/W	LKBI
1 May 67	1:48,000	1:12,000	B/W	LKBI
29 Oct 67	1:19,000	1:9,500	B/W	LKBI
28 Apr 68	1:19,000	1:9,500	B/W	LKBI
14 Nov 68	1:10,000	1:10,000	B/W	LKBI
29 Oct 69	1:40,000	1:10,000	Color	NOAA
30 May 70	1:48,000	1:12,000	B/W	SCS
24 Apr 71	1:19,000	1:9,500	B/W	LKBI
30 Apr 72	1:19,000	1:9,500	B/W	LKBI

NOTE: LKBI - Lockwood, Kessler, and Bartlett, Syosset, New York
NOAA - National Oceanic and Atmospheric Administration, Rockville, Maryland
SCS - Soil Conservation Service, Hyattsville, Maryland

Table 2

Total Area of Fire Island Within Site Boundary

	Date		
Year	Month	Day	Area x 10^4, m^2
62	4	19	283
62	10	12	295
63	3	14	290
63	10	31	321
64	5	7	331
64	10	16	278
65	5	14	261
65	10	25	269
66	3	27	242
66	11	14	256
67	5	1	247
67	10	29	258
68	4	28	258
68	11	14	247
69	10	29	268
70	5	30	259
71	4	24	281
72	4	30	262

Table 3

Total Ebb Tidal Delta Area, Encompassing Both the Main Outer Bar and the Shoal off Cedar Beach

Year	Date Month	Day	Code Number	Area x 10^3, m^2
62	4	19	200	999
62	10	12	200	888
63	3	14	200	538
63	10	31	200	770
64	5	7	200	1175
64	10	16	200	1859
65	5	14	200	1652
65	10	25	200	1471
66	3	27	200	1848
66	11	14	200	1660
67	5	1	200	1172
67	10	29	200	1211
68	4	28	200	1357
68	11	14	200	698
69	10	29	200	1033
70	5	30	200	1223
71	4	24	200	1243
72	4	30	200	868

Table 4

Total Flood Tidal Delta Area

Date			Code	
Year	Month	Day	Number	Area x 10^4, m^2
62	4	19	700	118
62	10	12	700	119
63	3	14	700	91
63	10	31	700	79
64	5	7	700	129
64	10	16	700	144
65	5	14	700	111
65	10	25	700	100
66	3	27	700	103
66	11	14	700	126
67	5	1	700	121
67	10	29	700	112
68	4	28	700	109
68	11	14	700	62
69	10	29	700	112
70	5	30	700	89
71	4	24	700	9
72	4	30	700	107

Table 5

Beach Area, Fire Island Subarea 10

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	410	45	510	109
62	10	12	410	40	510	109
63	3	14	410	56	510	139
63	10	31	410	107	510	169
64	5	7	410	154	510	137
64	10	16	410	72	510	165
65	5	14	410	122	510	148
65	10	25	410	132	510	133
66	3	27	410	37	510	146
66	11	14	410	44	510	151
67	5	1	410	67	510	142
67	10	29	410	52	510	149
68	4	28	410	70	510	145
68	11	14	410	61	510	148
69	10	29	410	62	510	141
70	5	30	410	70	510	183
71	4	24	410	190	510	128
72	4	30	410	71	510	164

Table 6

Beach Area, Fire Island Subarea 11

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	411	49	511	231
62	10	12	411	52	511	258
63	3	14	411	65	511	240
63	10	31	411	137	511	229
64	5	7	411	209	511	242
64	10	16	411	110	511	224
65	5	14	411	138	511	244
65	10	25	411	169	511	216
66	3	27	411	44	511	203
66	11	14	411	7	511	193
67	5	1	411	7	511	251
67	10	29	411	9	511	196
68	4	28	411	10	511	258
68	11	14	411	6	511	229
69	10	29	411	9	511	183
70	5	30	411	11	511	214
71	4	24	411	19	511	175
72	4	30	411	11	511	236

Table 7

Area of Democrat Point Spit

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	412	276	512	300
62	10	12	412	339	512	231
63	3	14	412	252	512	335
63	10	31	412	398	512	195
64	5	7	412	384	512	368
64	10	16	412	65	512	104
65	5	14	412	70	512	47
65	10	25	412	63	512	52
66	3	27	412	23	512	88
66	11	14	412	131	512	55
67	5	1	412	89	512	68
67	10	29	412	100	512	97
68	4	28	412	122	512	74
68	11	14	412	74	512	108
69	10	29	412	277	512	90
70	5	30	412	155	512	100
71	4	24	412	285	512	73
72	4	30	412	222	512	88

Table 8

Beach Area, Fire Island Subarea 13

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	413	66	513	58
62	10	12	413	110	513	30
63	3	14	413	54	513	40
63	10	31	413	45	513	21
64	5	7	413	79	513	41
64	10	16	413	62	513	32
65	5	14	413	32	513	25
65	10	25	413	36	513	26
66	3	27	413	63	513	22
66	11	14	413	43	513	22
67	5	1	413	50	513	17
67	10	29	413	31	513	33
68	4	28	413	52	513	36
68	11	14	413	44	513	38
69	10	29	413	30	513	27
70	5	30	413	41	513	30
71	4	24	413	58	513	28
72	4	30	413	44	513	30

Table 9

Beach Area, Oak Beach Subarea 20

Date			Foreshore	
Year	Month	Day	Code No.	Area x 10^3, m^2
62	4	19	420	33
62	10	12	420	30
63	3	14	420	32
63	10	31	420	27
64	5	7	420	35
64	10	16	420	39
65	5	14	420	36
65	10	25	420	32
66	3	27	420	33
66	11	14	420	34
67	5	1	420	26
67	10	29	420	29
68	4	28	420	46
68	11	14	420	35
69	10	29	420	31
70	5	30	420	32
71	4	24	420	38
72	4	30	420	38

Table 10

Beach Area, Oak Beach Subarea 21

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	421	26	521	61
62	10	12	421	22	521	56
63	3	14	421	30	521	37
63	10	31	421	20	521	50
64	5	7	421	23	521	42
64	10	16	421	28	521	33
65	5	14	421	20	521	30
65	10	25	421	26	521	34
66	3	27	421	27	521	27
66	11	14	421	22	521	19
67	5	1	421	17	521	20
67	10	29	421	20	521	24
68	4	28	421	33	521	25
68	11	14	421	25	521	20
69	10	29	421	20	521	14
70	5	30	421	23	521	25
71	4	24	421	25	521	28
72	4	30	421	22	521	19

Table 11

Beach Area, Sand Dike Subarea 22

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	422	98	522	145
62	10	12	422	58	522	142
63	3	14	422	71	522	144
63	10	31	422	42	522	164
64	5	7	422	49	522	167
64	10	16	422	32	522	168
65	5	14	422	50	522	166
65	10	25	422	43	522	168
66	3	27	422	46	522	160
66	11	14	422	48	522	171
67	5	1	422	51	522	169
67	10	29	422	48	522	184
68	4	28	422	48	522	170
68	11	14	422	47	522	196
69	10	29	422	41	522	194
70	5	30	422	48	522	190
71	4	24	422	53	522	200
72	4	30	422	48	522	192

Table 12

Beach Area, Cedar Beach Subarea 23

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	423	37	523	173
62	10	12	423	38	523	123
63	3	14	423	55	523	187
63	10	31	423	32	523	159
64	5	7	423	36	523	179
64	10	16	423	20	523	147
65	5	14	423	36	523	128
65	10	25	423	38	523	105
66	3	27	423	25	523	121
66	11	14	423	40	523	98
67	5	1	423	41	523	91
67	10	29	423	42	523	72
68	4	28	423	41	523	103
68	11	14	423	23	523	156
69	10	29	423	30	523	103
70	5	30	423	31	523	109
71	4	24	423	45	523	133
72	4	30	423	28	523	135

Table 13

Beach Area, Cedar Beach Subarea 24

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	424	83	524	265
62	10	12	424	56	524	237
63	3	14	424	68	524	249
63	10	31	424	48	524	245
64	5	7	424	61	524	230
64	10	16	424	36	524	244
65	5	14	424	46	524	223
65	10	25	424	50	524	223
66	3	27	424	27	524	226
66	11	14	424	36	524	211
67	5	1	424	33	524	207
67	10	29	424	34	524	208
68	4	28	424	42	524	202
68	11	14	424	23	524	209
69	10	29	424	5	524	10
70	5	30	424	30	524	188
71	4	24	424	42	524	164
72	4	30	424	30	524	130

Table 14

Beach Area, Cedar Beach Subarea 25

Date			Foreshore		Backshore	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	425	58	525	116
62	10	12	425	57	525	100
63	3	14	425	2	525	14
63	10	31	425	40	525	99
64	5	7	425	62	525	94
64	10	16	425	33	525	209
65	5	14	425	52	525	189
65	10	25	425	65	525	183
66	3	27	425	38	525	206
66	11	14	425	54	525	181
67	5	1	425	56	525	184
67	10	29	425	53	525	165
68	4	28	425	64	525	197
68	11	14	425	22	525	197
69	10	29	425	0	525	0
70	5	30	425	28	525	188
71	4	24	425	54	525	186
72	4	30	425	75	525	163

Table 15

Total Longshore Bar Area

Date				
Year	Month	Day	Code No.	Area x 10^3, m^2
62	4	19	310	117
62	10	12	310	120
63	3	14	310	105
63	10	31	310	0
64	5	7	310	0
64	10	16	310	0
65	5	14	310	0
65	10	25	310	0
66	3	27	310	0
66	11	14	310	0
67	5	1	310	0
67	10	29	310	0
68	4	28	310	0
68	11	14	310	0
69	10	29	310	0
70	5	30	310	0
71	4	24	310	0
72	4	30	310	0

Table 16

Dune Areas on Fire Island

Date			Landward of Scarp		Seaward of Scarp	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	610	1611	611	96
62	10	12	610	1526	611	216
63	3	14	610	1187	611	34
63	10	31	610	1380	611	38
64	5	7	610	1199	611	1
64	10	16	610	1407	611	26
65	5	14	610	1263	611	1
65	10	25	610	1342	611	17
66	3	27	610	1291	611	26
66	11	14	610	1368	611	117
67	5	1	610	1213	611	22
67	10	29	610	1353	611	236
68	4	28	610	1217	611	31
68	11	14	610	1222	611	166
69	10	29	610	1289	611	193
70	5	30	610	1204	611	126
71	4	24	610	1186	611	77
72	4	30	610	1158	611	119

NOTE: Areas landward of scarp are above highest nonstorm tides. Areas seaward of scarp are "outliers" of remnant dunes within adjacent beach areas.

Table 17

Dune Areas on Oak and Cedar Beaches

Date			Landward of Scarp		Seaward of Scarp	
Year	Month	Day	Code No.	Area x 10^3, m^2	Code No.	Area x 10^3, m^2
62	4	19	620	112	621	121
62	10	12	620	117	621	61
63	3	14	620	108	621	101
63	10	31	620	118	621	92
64	5	7	620	111	621	77
64	10	16	620	115	621	111
65	5	14	620	119	621	68
65	10	25	620	124	621	26
66	3	27	620	114	621	45
66	11	14	620	125	621	213
67	5	1	620	111	621	0
67	10	29	620	112	621	178
68	4	28	620	113	621	64
68	11	14	620	112	621	206
69	10	29	620	115	621	184
70	5	30	620	117	621	329
71	4	24	620	114	621	98
72	4	30	620	112	621	331

NOTE: Areas landward of scarp are above highest nonstorm tides. Areas seaward of scarp are "outliners" of remnant dunes within adjacent beaches.

Table 18

Total Nonvegetated and Developed Areas

Above Highest Nonstorm Tides

Year	Date Month	Day	Fire Island Code No.	Fire Island Area x 10^3, m^2	Fire Island Code No.	Fire Island Area x 10^3, m^2
62	4	19	810	171	820	176
62	10	12	810	180	820	176
63	3	14	810	173	820	173
63	10	31	810	190	820	178
64	5	7	810	172	820	178
64	10	16	810	198	820	179
65	5	14	810	177	820	187
65	10	25	810	187	820	189
66	3	27	810	182	820	182
66	11	14	810	186	820	190
67	5	1	810	172	820	187
67	10	29	810	184	820	195
68	4	28	810	176	820	192
68	11	14	810	171	820	185
69	10	29	810	180	820	174
70	5	30	810	169	820	190
71	4	24	810	173	820	193
72	4	30	810	166	820	191

NOTE: Includes roads, parking lots, buildings, and cleared areas.

Table 19

Beach Widths of the Component Segments of Fire Island, Oak Beach, and Cedar Beach in Metres

Date	410+510	411+511	413+513	420+520	421+521	422+522	423+523	424+524	425+525
19 Apr 62	92	137	42	13	62	135	178	314	194
12 Oct 62	90	150	47	12	56	112	136	264	176
14 Mar 63	117	148	32	13	48	120	204	286	19+
31 Oct 63	165	178	22	11	50	115	160	265	156
7 May 64	174	219	40	14	46	120	182	213	174
16 Oct 64	142	162	32	16	44	111	142	253	271
14 May 65	161	186	19	14	36	120	139	243	269
25 Oct 65	158	187	21	13	43	118	121	246	276
27 Mar 66	110	120	28	13	39	115	123	229	272
14 Nov 66	116	128	22	14	30	122	117	223	262
1 May 67	125	158	23	10	27	123	112	217	267
29 Oct 67	120	143	22	12	32	130	96	219	243
28 Apr 68	129	176	30	18	42	122	121	221	291
14 Nov 68	125	145	28	14	33	135	151	210	244
29 Oct 69	121	133	19	12	25	131	112	14	0
30 May 70	151	161	24	13	34	133	118	197	242
24 Apr 71	190	178	29	15	38	141	150	187	269
30 Apr 72	140	171	25	15	30	134	138	145	266
Beach segment length	1680	2060	3000	2540	1410	1800	1190	1110	900

NOTE: The beach widths are calculated by dividing the area of the segment by the segment length. The beach widths do not correspond necessarily with shoreline progradation or recession.

APPENDIX A: AERIAL MOSAICS (PHOTO A, 18 SHEETS)

Photo A . Fire Island Inlet, April 1962 (sheet 1 of 18)

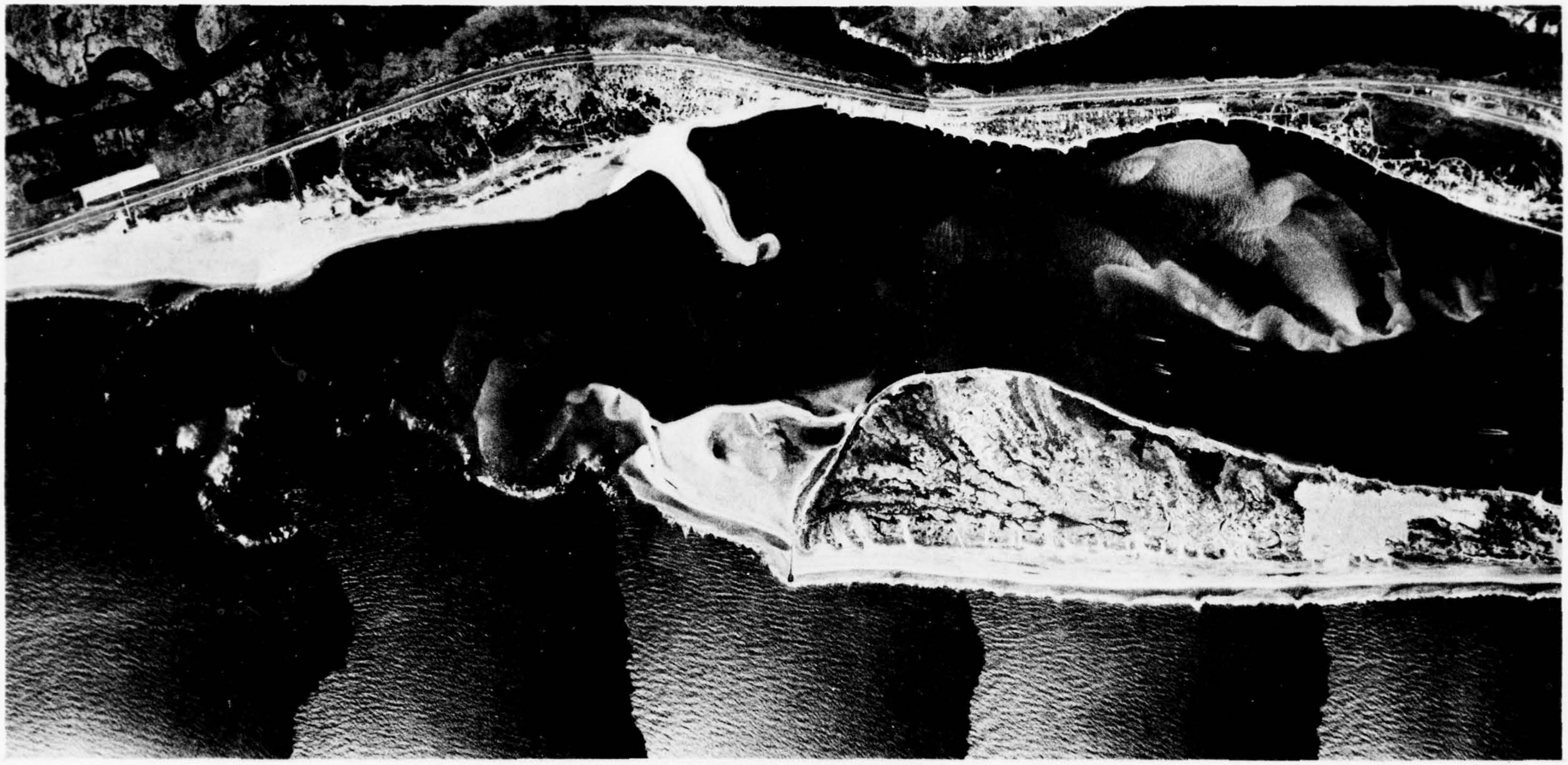


Photo A . October 1962 (sheet 2 of 18)

Photo A . March 1963 (sheet 3 of 18)

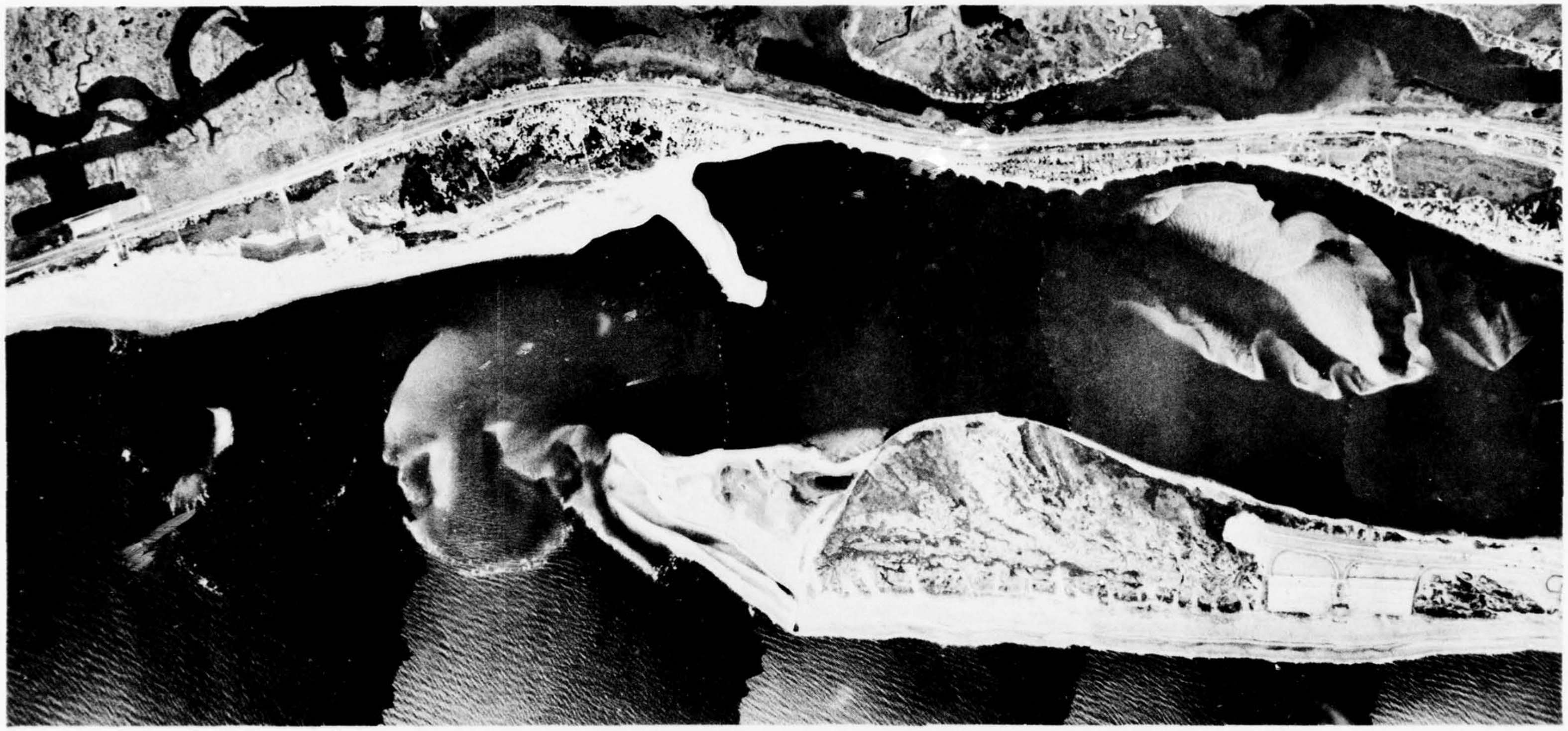


Photo A . October 1963 (sheet 4 of 18)

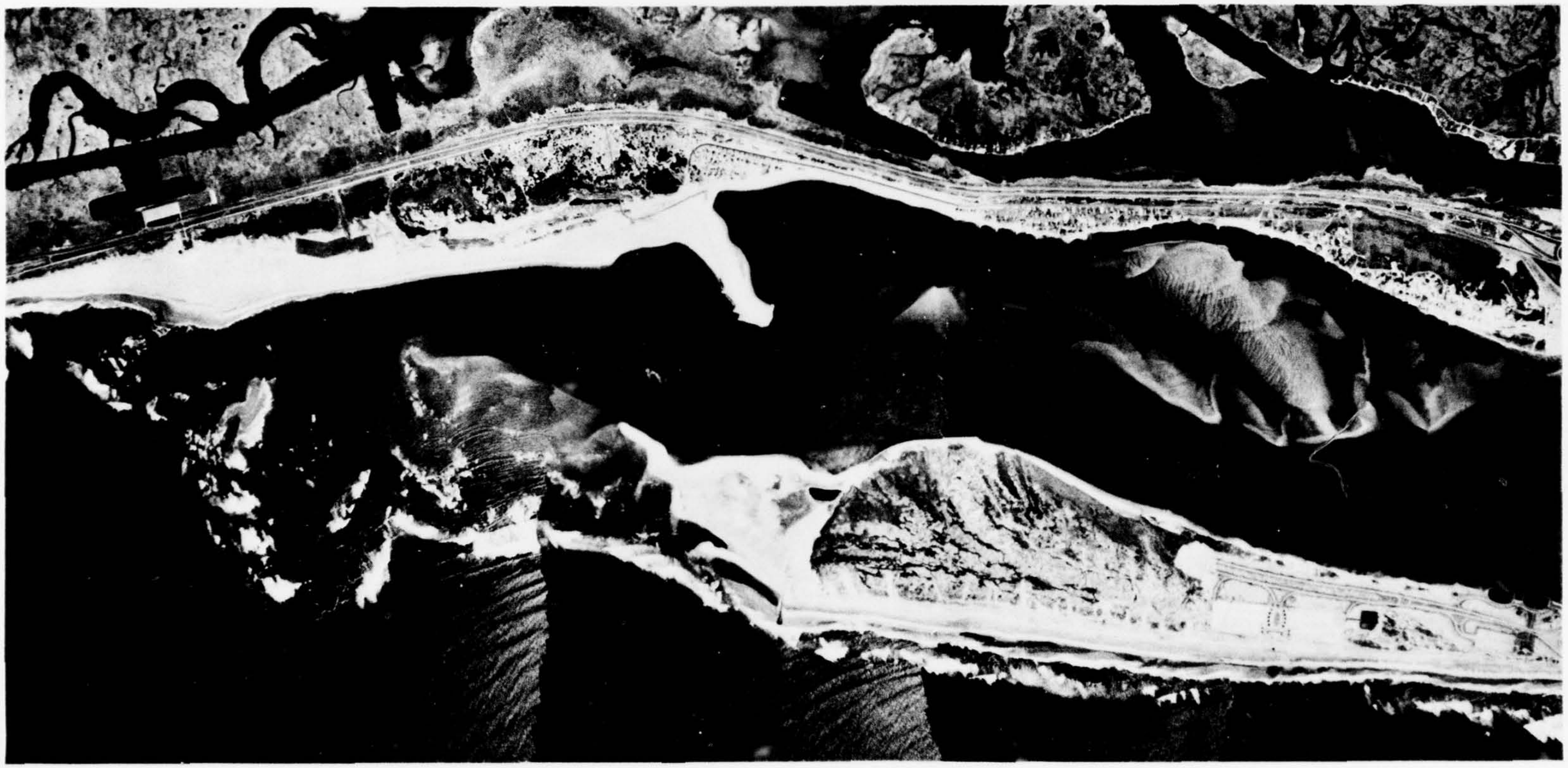


Photo A . May 1964 (sheet 5 of 18)

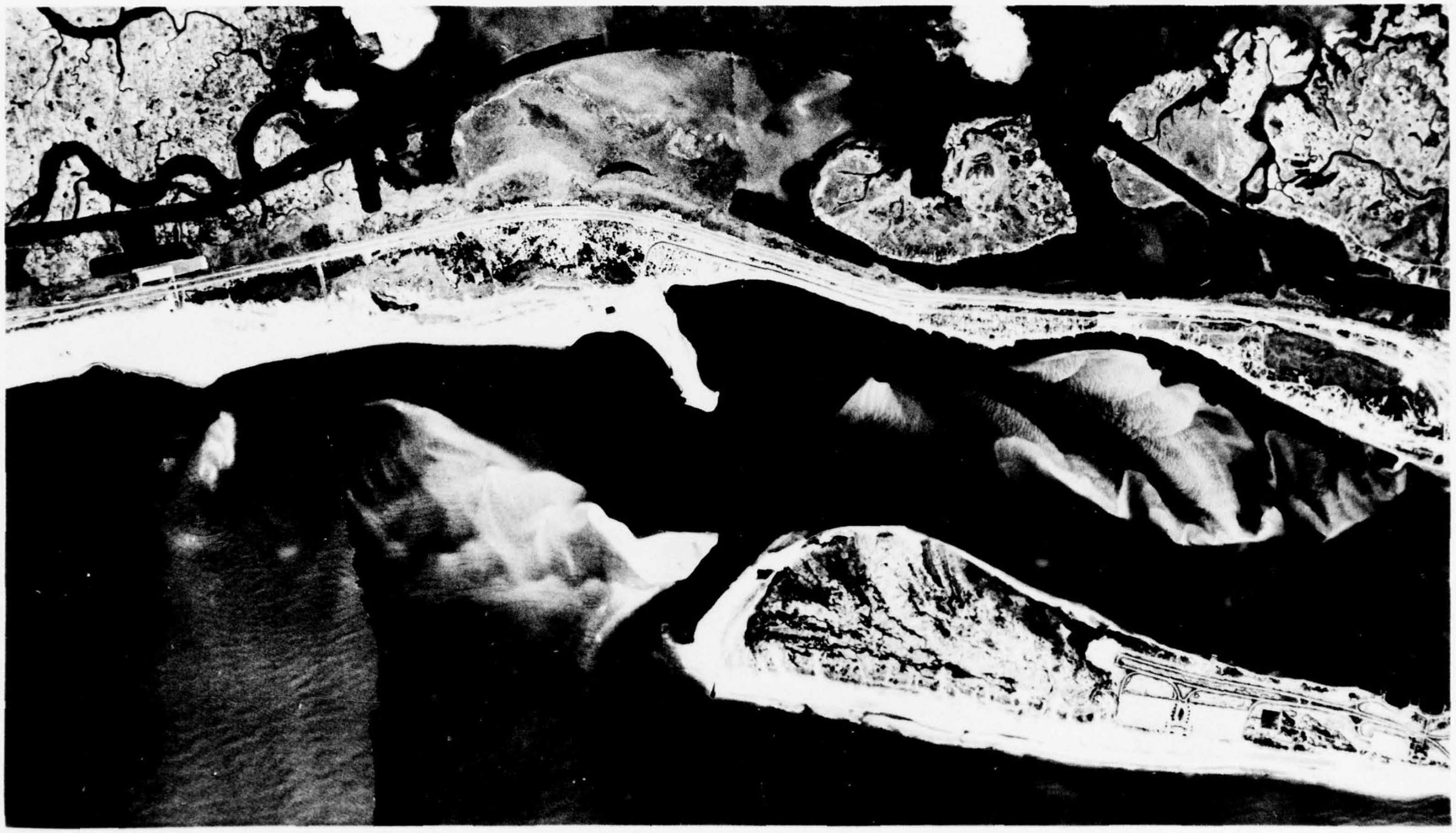


Photo A . October 1964 (sheet 6 of 18)

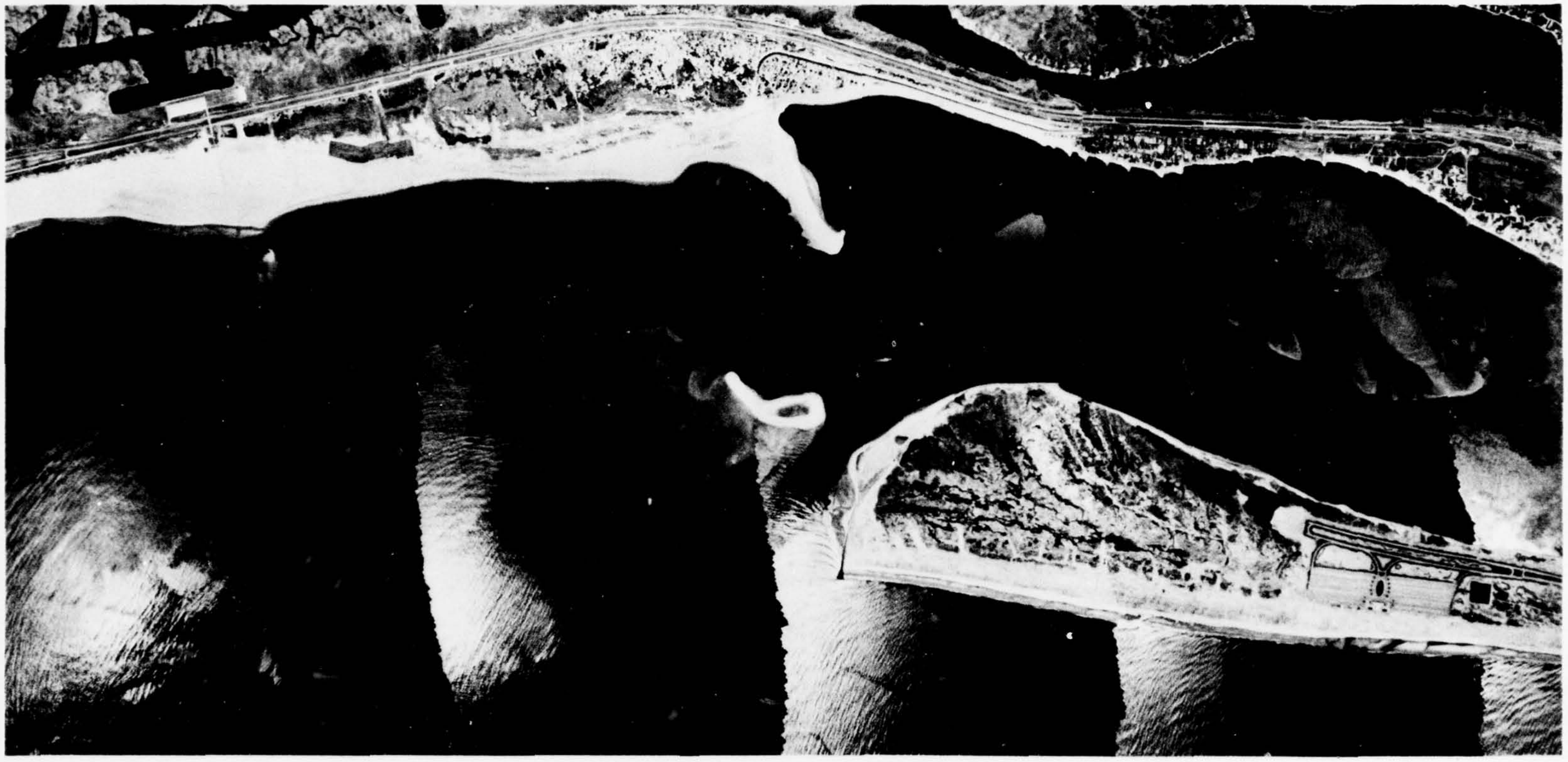


Photo A . May 1965 (sheet 7 of 18)

Photo A . October 1965 (sheet 8 of 18)

Photo A . March 1966 (sheet 9 of 18)

Photo A . November 1966 (sheet 10 of 18)

Photo A . May 1967 (sheet 11 of 18)

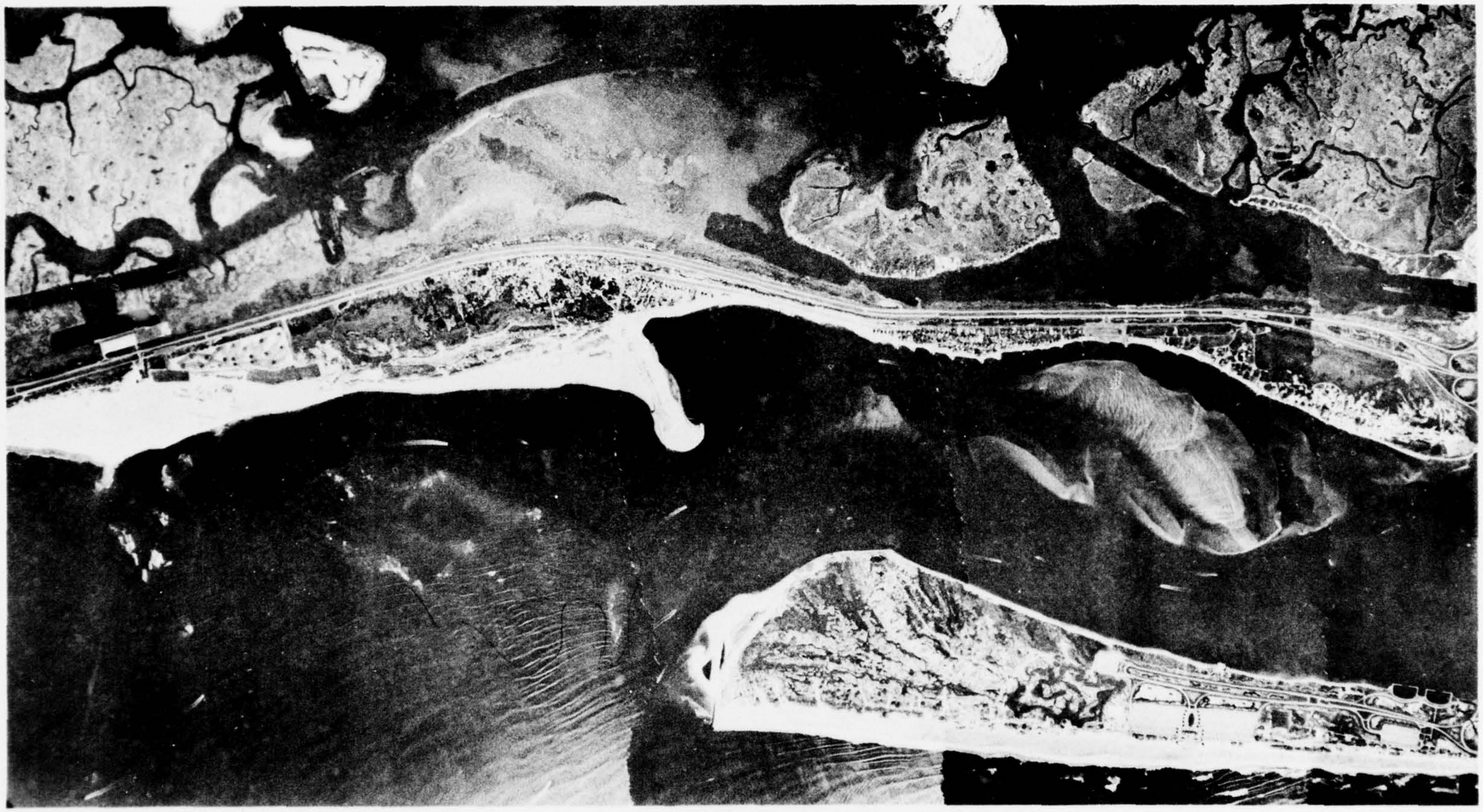


Photo A . October 1967 (sheet 12 of 18)

Photo A . April 1968 (sheet 13 of 18)

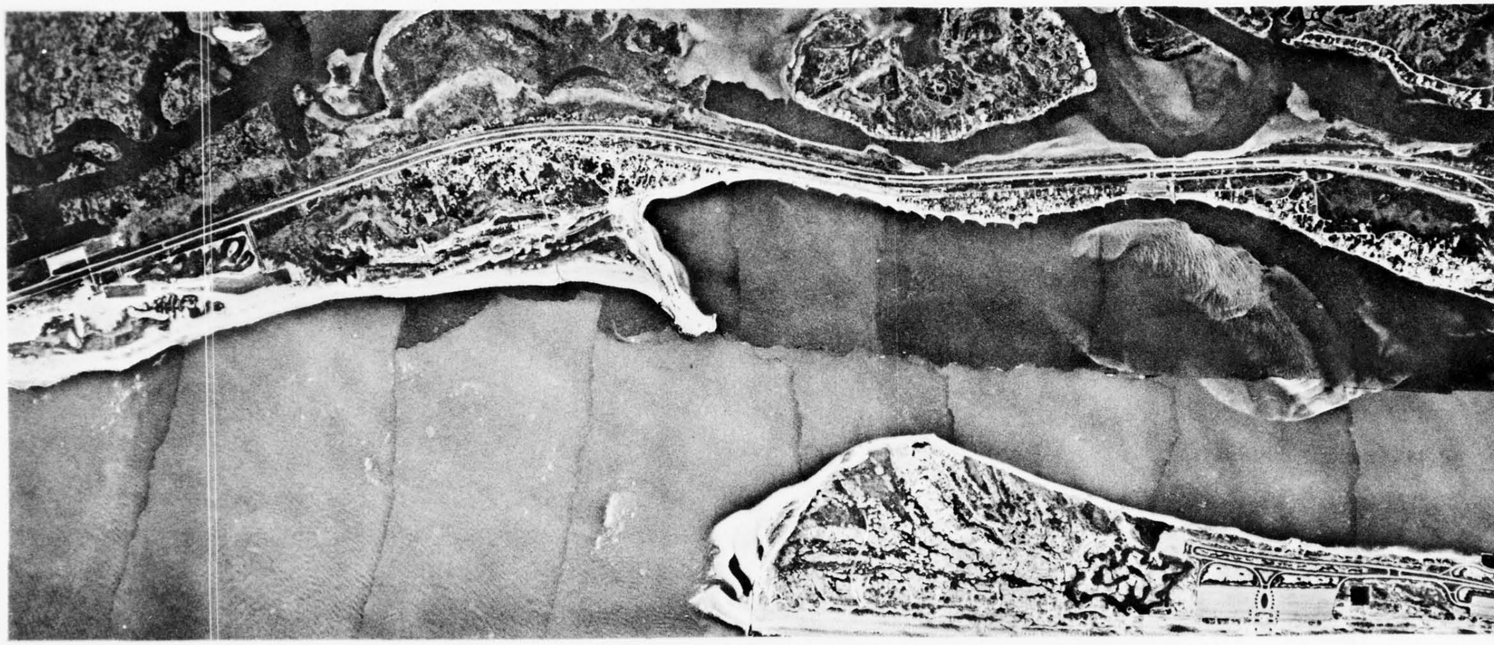


Photo A . November 1968 (sheet 14 of 18)

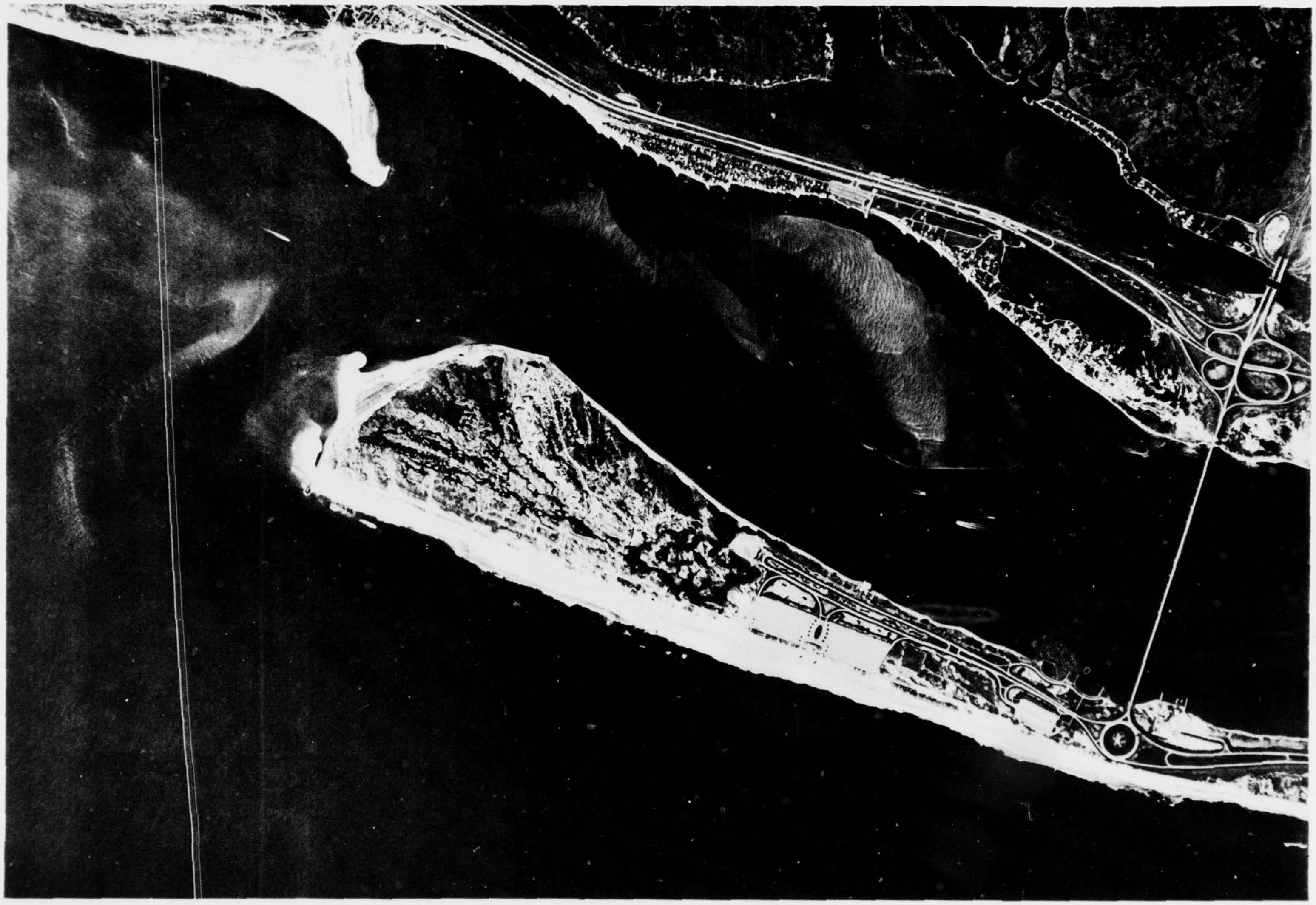


Photo A . October 1969 (sheet 15 of 18)

Photo A . May 1970 (sheet 16 of 18)

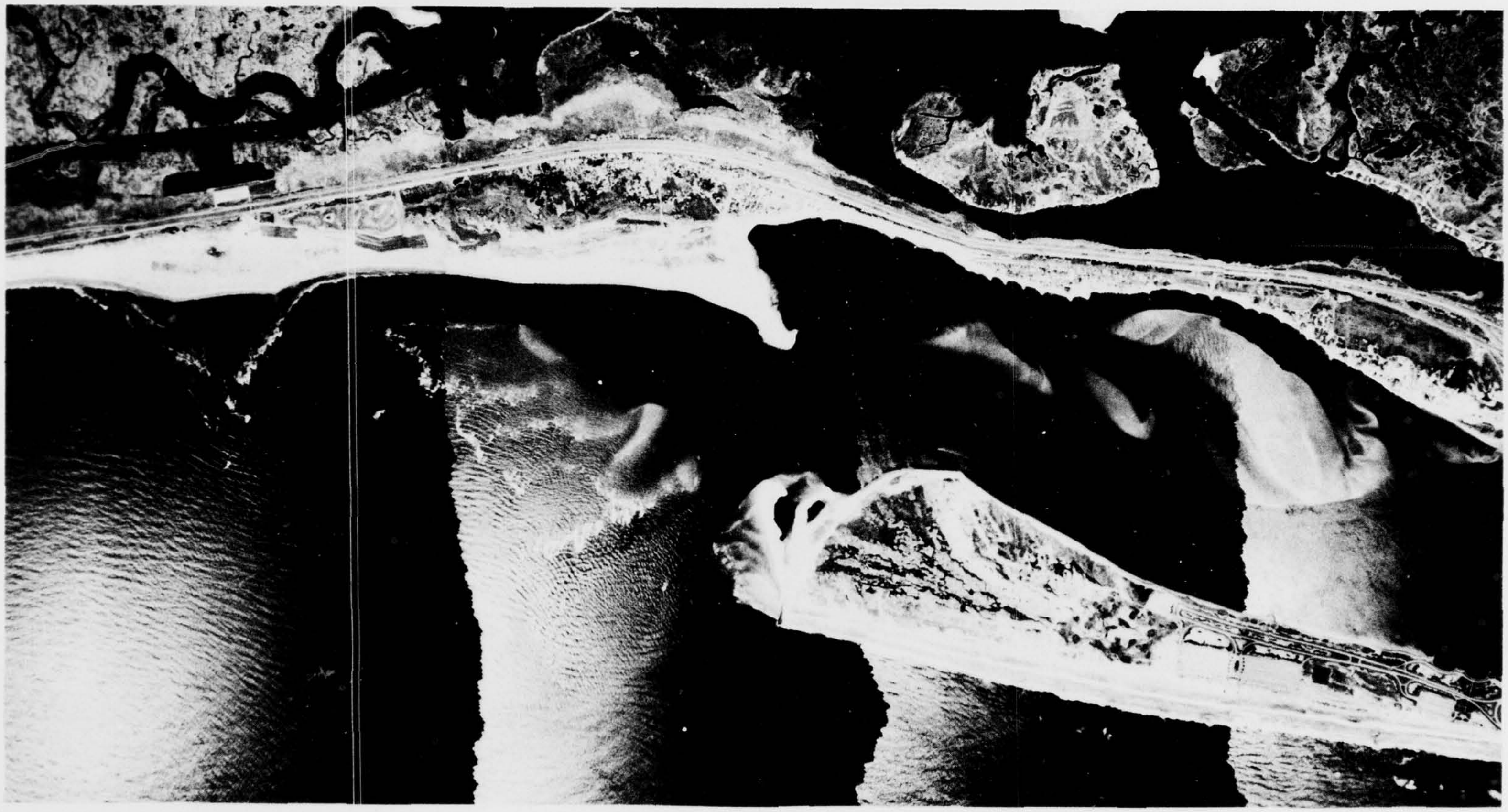


Photo A . April 1971 (sheet 17 of 18)

Photo A . April 1972 (sheet 18 of 18)

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Barwis, John H

A computer-aided aerial photographic analysis of Fire Island Inlet geomorphology / by John H. Barwis, Frederick C. Perry, Victor E. LaGarde. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1977.

45, [19], 18 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; H-77-12)

Prepared for U. S. Army Engineer District, New York, New York, New York.

1. Fire Island Inlet. 2. Geomorphology. 3. Photographic analysis. I. LaGarde, Victor E., joint author. II. Perry, Frederick C., joint author. III. United States. Army. Corps of Engineers. New York District. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; H-77-12.

TA7.W34m no.H-77-12